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REMOTE SENSING APPLICATIONS TO RESOURCE PROBLEMS IN SOUTH DAKOTA

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National Aeronautics and Space Administration
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Washington, D.C.

July 1, 1979 - December 31, 1979

Semi-Annual Progress Report
Grant No. NGL 42-003-007

Remote Sensing Institute
South Dakota State University
Brookings, South Dakota 57007

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REMOTE SENSING APPLICATIONS
TO RESOURCE PROBLEMS IN SOUTH DAKOTA

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ABSTRACT

Cooperative remote sensing projects between RSI and various South Dakota local and state agencies are an important means of introducing new techniques or improving current operations. The remote sensing projects in this report address current and important areas of concern within the state of South Dakota. In FY 1980 eight projects are being conducted; the following titled paragraphs abstract each project's progress.

Detection of High Moisture Zones Under Interstate Highways

High moisture zones adjacent to Interstate 90 in western South Dakota are associated with highway warping and/or pavement breakup. Location of the high moisture zones indicates areas where drainage tiles can be installed to ease the problem. Thermal and color infrared imagery were collected at three altitudes (305, 914, 2472 m) on two dates (5/24/79 and 9/14/79) over two studv areas, a 20-mile segment of I-90 near Rapid City and an 8-mile segment of I-90 near Chamberlain. Visual analysis and level slicing (thermal imagery only) has revealed that predawn thermal imagery (2 a.m. LST) appeared best for locating high moisture zones in the Rapid City area. Color infrared imagery was of valuable assistance with the thermal imagery in Rapid City site, and by itself in the Chamberlain area it was more useful than either midday or predawn thermal imagery for locating high moisture zones. The results are preliminary and further analysis and field data are needed to verify the utility of the various imagery-altitude-date combinations.

Thermal Infrared Censusing of Canada Geese in South Dakota

Current methods for censusing Canada goose concentrations on the mainstem reservoirs in South Dakota have sizeable errors. Many geese are feeding away from the reservoir during counts and return only in the evening resulting in significant errors. The objective of this project is to determine the feasibility of an operational inventory utilizing aerial thermography collected during the night when all geese are resting on the water. The thermal infrared emissivity of central flyway geese was measured at .962 ± .017. There were no significant differences in emissivities between species of Canada and Snow geese or between adults and immature. Models have been developed to predict the apparent temperature of Canada geese at varying environmental temperatures. Aerial thermography were collected 16 November 1979. Canada geese could be identified on thermography collected with a trimetal detector at altitudes as high as 1500' AGL. Geese could not be resolved on altitudes greater than 1500' AGL or on data collected with a photovoltaic detector.

Dutch Elm Disease Detection in Urban Environment

Dutch elm disease is fatal to nearly all elm trees. The disease is transmitted by beetles which survive in the dead or dying trees. Removal of infected trees is the only effected method to control the disease. Economic loss, including removal of dead trees was $22 million in South Dakota in 1978. The city of Watertown and South Dakota Division of Forestry are cooperating with the Remote Sensing Institute to use remote sensing data for early detection and removal of infected trees before the disease is spread.

A Feasibility Study for Monitoring Effective Precipitation in South Dakota Using TIROS-N

An investigation was initiated to evaluate the utility of using TIROS-N data to evaluate effective precipitation for use in a soil moisture network in South Dakota. Rainfall data were supplied by the 1500 gauge network operated by the South Dakota Department of Water and Natural Resources. A network of 81 soil sampling sites was established throughout the state to measure soil moisture on a repetive basis. TIROS-N data are being compared with rainfall and soil moisture measurements to locate reflectance/emittance anomalies associated with moisture distribution.

Open and Abandoned Dump Sites in Spink County

There are numerous open and abandoned solid waste dump sites in existance which are utilized without sound environmental practices. Several government agencies are addressing this solid waste management problem. One major problem is determining how many and where they exist. Remote sensing techniques have successfully been used to identify the location of these sites and provide other resource information concerning pollution potential.

Influence of Soil Reflectance on Landsat Signatures of Crops

Photo-interpreted strata (10) are being evaluated as a means of improving crop classification from Landsat CCT's. Progress to-date includes ground enumeration of 255 segments, error checking and other data extraction procedures on a 25 August 1979 CCT, and initial preparation of data files for analysis. Eventual analysis will include clustering, a statistical evaluation of the variables, i.e. strata, segments, fields (crop), and stage of crop maturity. Scene classification and multitemporal analysis (20 July and 25 August CCT) are probable. Utilization of results are possible by ESCS, Crop Reporting Districts, and others whose interests are furthered by increasing the accuracy of crop-area estimations. In 1979 sunflowers increased dramatically in area; this study will evaluate Landsat classification and estimation of sunflower area in Spink County, South Dakota.

Model Implementation Program - Lake Herman Watershed

The Lake Herman watershed in southeastern South Dakota was selected as one of seven watersheds in the United States for involvement in the national pilot Model Implementation Program (MIP). Remote Sensing Institute is cooperating with numerous other states and local agencies to provide baseline and continuous resource information for watershed management. An information system including land cover, soil series, slope, drainage and land treatment is being used to locate land in need of treatment, sites suitable for sediment control structures and estimate sediment delivery to the lake.

Six-Mile Investigation Follow-On

An investigation of Six-Mile Creek Watershed, located in southeastern South Dakota, was conducted in FY 79 to develop and apply remote sensing techniques to assess the geohydrology and the environment of the watershed to evaluate the impact of a proposed dam and recreation site on Six-Mile Creek. As part of the original investigation, SCS geologists used thermal imagery to select sites for drilling observation wells to provide information for designing seepage and cutoff controls. A follow-on to the original investigation was requested to document the results of the drilling. The drilling, which occurred in August 1979, verified the presence of permeable alluvium and near-surface groundwater in the vicinity of the proposed dam.

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ACKNOWLEDGEMENTS

These applications projects are funded by the National Aeronautics and Space Administration (NASA) and the State of South Dakota. Additional funding by the South Dakota Department of Transportation is acknowledged. Appreciation is extended to the NASA technical officer, Mr. Joe Vitale, for his support of these projects.

REMOTE SENSING APPLICATIONS TO RESOURCE PROBLEMS IN SOUTH DAKOTA

The Remote Sensing Institute is actively cooperating with various local, state, federal agencies in South Dakota to effect the transfer of remote sensing technology. These cooperative endeavors, or projects, are made possible through the funding of NASA Office of Space & Terrestrial Applications, the state of South Dakota, and several of the cooperating agencies. It is the major objective of these projects to: 1) introduce new techniques to local, state, or federal agencies in addressing certain resource problems of South Dakota; and/or 2) provide alternative methods of improving current practices or procedures. This report provides an assessment of progress on each of the eight projects' goals and objectives.

DETECTION OF HIGH MOISTURE ZONES UNDER INTERSTATE HIGHWAYS

Introduction

During the Cretaceous Period 60 to 100 million years before present, the Pierre Formation was laid down on a muddy sea bottom (Laird, 1957). This sedimentary formation, which consists of dense shales weathering to expanding clays, is the dominant geologic parent material throughout the central one-third of western South Dakota. The so-called Pierre shale possesses numerous detrimental physical and chemical properties which strongly influence, among other activities, highway construction and roadbed degradation (Hoskins and Hammerquist, 1970).

Interstate 90 traverses the Pierre shale throughout its western South Dakota route. Fortunately, stabilization of the subgrade materials of the I-90 roadbed has been largely successful and all but localized, extremely warped areas have been controlled (McDonald, 1970). It is these extreme areas that have been topic of several studies aimed at characterizing and examining this problem in relation to highway break-up (Bruce and Scully, 1966; McDonald, 1970; and Hoskins et al., 1971). These studies have thoroughly enumerated the morphology of the problem, e.g. landslides, water movement along joints and bedding planes, and moisture and slope stability problems at cut and fill sections in the Pierre shale.

McDonald (1970) outlined three possible methods of ameliorating roadbed warping problems in the Pierre shale region. Resistivity, coring, and infrared photography were suggested methods of characterizing the moisture conditions of road cuts. McDonald also recorded the intention of the South Dakota Department of Transportation (DOT) to investigate all open cut sections (in the Pierre Formation) along Interstate and primary routes in South Dakota.

A research study conducted on I-90 east of Rapid City reported the use of ground and aerial photography to locate fracture zones associated with roadbed break-up (Hoskins et al., 1971). Results indicated that low altitude color and color infrared photography provided the most useful information. However, results also revealed no significant difference in the depth to water table in fracture traces vs. nonfracture zones. Other mechanisms (i.e. primary and secondary discontinuities) of water movement in the Pierre Formation have been detailed (Bruce and Scully, 1966).

Other remote sensing studies have shown thermal infrared imagery to be a useful tool for describing engineering soil units (Rib, 1975). Nighttime thermal imagery was found to be better than daytime imagery for identifying areas of high moisture over bedrock (Stallard and Myers, 1972). A detailed examination of thermal infrared data - its characteristics, utility, and applicability in soil moisture determination - is presented in Heilman et al. (1978).

Warping and/or breakup of highway pavement is a serious and costly problem. It appears that corrective procedures can diminish the effects of the shrink-swell of the Pierre shale. The major objective of this study was to investigate color infrared aerial photography (CIR) and thermal infrared imagery as tools to precipitate the early location of potential problem areas. The importance of this lies in the fact that corrective procedures initiated at an early stage of highway deterioration can save tax dollars and also reduce the discomfort of bumpy and broken highways.

Study Area

A 20-mile segment of I-90 near Rapid City, representative of highway break-up problems, was selected as the primary study area (Figure 1). Fracture zones in parts of this area have been previously documented (Hoskins et al., 1971). The study area is located in a warm, very dry plain with an annual rainfall of 35 to 43 cm (14 - 17 in). Soils have formed in Pierre shale and in high terraces; an interface between terrace depositions and Pierre shale adds another potential mechanism for lateral conductance of ground water.

A secondary site near Chamberlain was added to the project in mid-summer to provide a different set of conditions (Figure 2). This site lies in a warm, dry plain with a rainfall of around 43 cm (17 in). Soils have formed in the Pierre shale. The rolling to steeply breaking topography often exposes several members of the Pierre Formation. This region has a good potential for landslides.

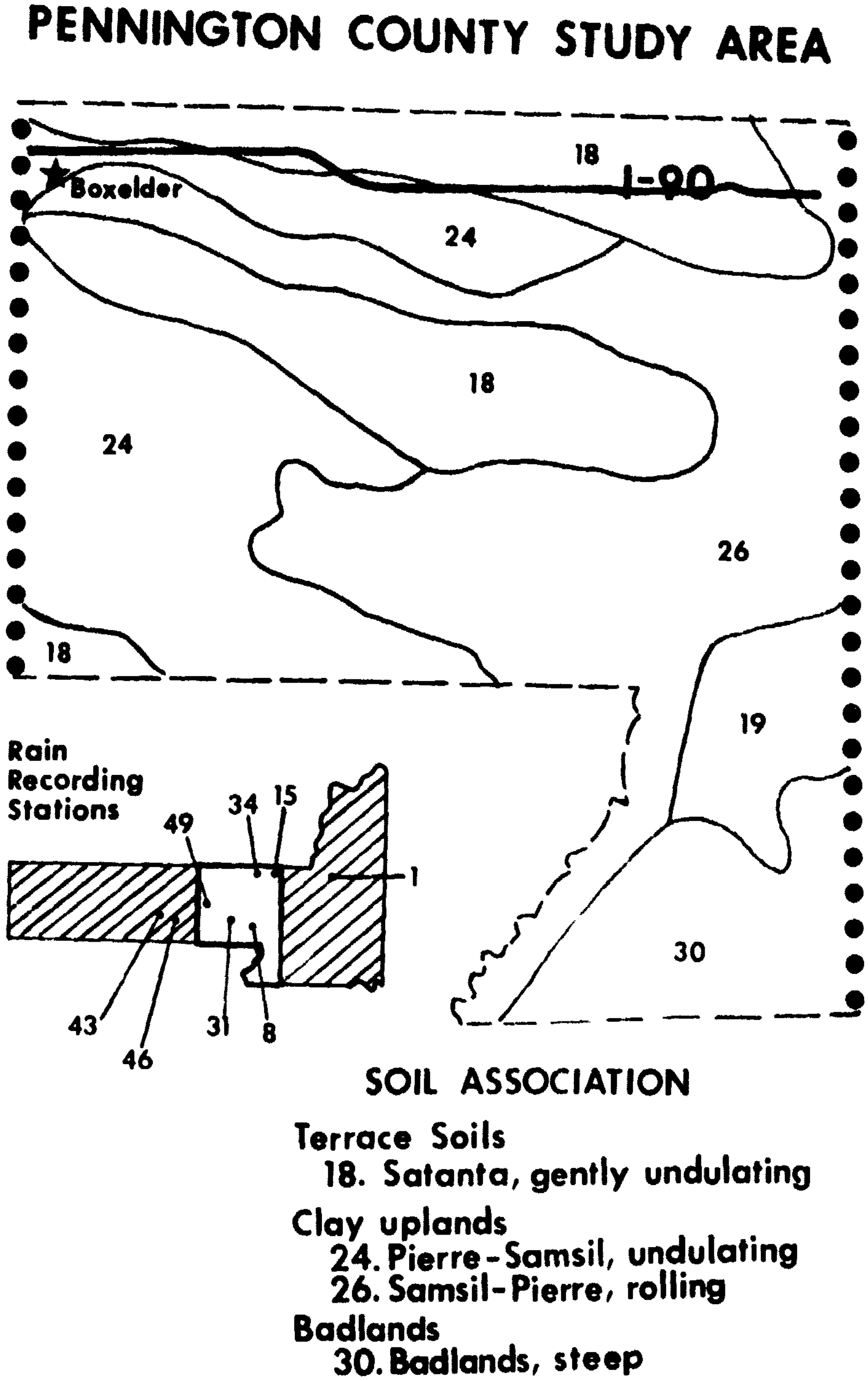


Figure 1. Location of I-90 study section and the soils of surrounding region. Precipitation recording stations are also located. (See Table 2).

CHAMBERLAIN STUDY AREA

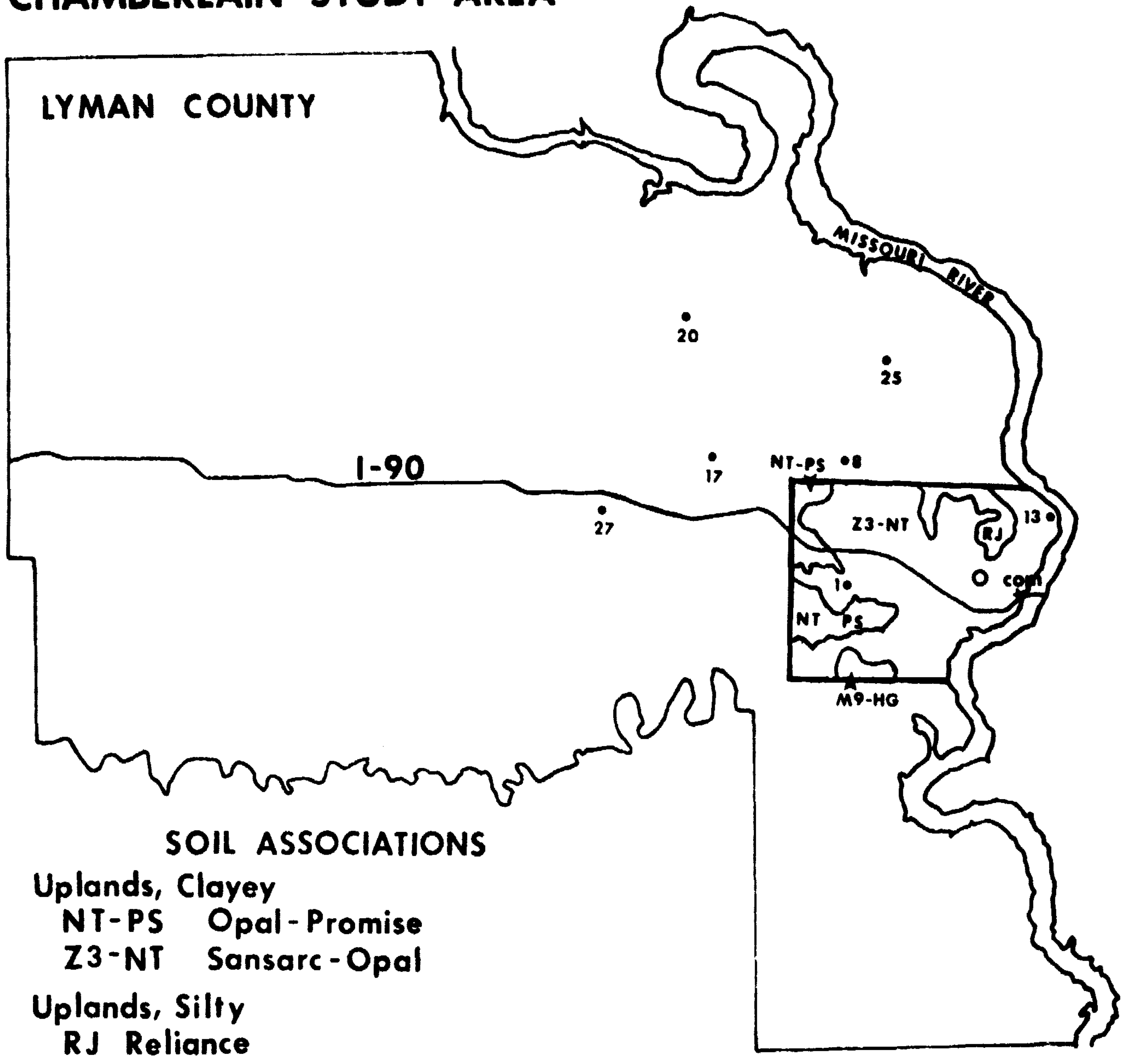


Figure 2. Location of Chamberlain study area. Precipitation recording stations are the numbered positions in and surrounding the study site. (See Table 2).

Table 1. Aerial data collected for 1980 DOT project.

Data	Site	Date	Altitude Above Ground Level (m) 305	914	2742	Range of Apparent Ground Temp.	Notes
Thermal (4.5-5.5 μm)	Rapid City	5/24/79	x			20 to 44° C	Day flight[§]
				x		14 to 35.5° C	
					x	10 to 32° C	
Color infrared photography[†] (.51 to .91 μm)	Rapid City	5/24/79		x			
Thermal (4.5-5.5 μm)	Rapid City	5/25/79	x			10 to 20° C	Predawn flight
Thermal (8.7-11.5 μm)	Rapid City	9/14/79	x			6 to 46° C	Day flight
				x		6 to 46° C	
					x	6 to 46° C	
Color infrared photography (.51 to .91 μm)	Rapid City	9/14/79		x			
Thermal (8.7-11.5 μm)	Rapid City	9/15/79	x			-4 to 16° C	Predawn flight, temp. inversion
				x		-4 to 16° C	
Thermal (8.7-11.5 μm)	Chamberlain	9/15/79	x			20 to 50° C	Day flight
				x		20 to 50° C	
Color infrared photography (.51 to .91 μm)	Chamberlain	9/15/79		x			
Thermal (8.7-11.5 μm)	Chamberlain	9/16/79	x			1 to 21° C	Predawn flight, temp. inversion
				x		1 to 21° C	

[†]One pass centered on highway with 60% endlap.

[§]All day flights took place at approx. 2 p.m. local standard time (LST) while night or predawn flights took place at approx. 2 a.m. LST.

Methods and Materials

Thermal imagery and CIR photography were collected twice for the Rapid City site and once for the Chamberlain site. Further pertinent details of each flight are outlined in Table 1. All flights took place under cloudless skies. The 4.5 to 5.5 μm detector was used in the initial flight due to malfunction in the 8.7 to 11.5 μm detector.

Neither of the sites had received any rainfall immediately prior to the aerial flights. Precipitation recorded during the growing season is detailed by monthly totals and recording station (Table 2).

Table 2. Precipitation records for area around study sites (data provided courtesy of Department of Water and Natural Resources, Pierre).

	Precipitation (centimeters)						
Station	April	May	June	July	Aug.	Sept.	TOTAL
Pennington County							
2-15†	2.1	2.9	13.2	8.7	4.5	.2	31.6(12.45 inches)
2-31	.6	2.9	10.3	13.7	5.7	0	33.2(13.08 inches)
2-34	1.3	3.3	12.6	10.1	4.7	0	32.0(12.56 inches)
2-43	N/A	1.3	13.1	12.4	6.8	0	33.6(13.23 inches)
2-46	N/A	N/A	10.3	11.6	7.0	.1	29.0(11.41 inches)
2-49	4.4	2.7	9.1	8.5	4.9	6.2	35.8(14.17 inches)
Lyman County							
45-01	4.6	5.0	5.3	13.2	5.7	0	33.8(13.33 inches)
45-08	5.4	N/A	6.3	13.9	9.3	0	34.9(13.76 inches)
45-13	7.3	5.8	10.3	N/A	5.2	N/A	28.6(11.26 inches)
45-17	.8	6.1	6.2	12.2	6.9	0	32.2(12.67 inches)
45-20	4.2	5.2	14.7	12.8	7.7	N/A	44.6(17.59 inches)
45-25	5.7	7.3	10.7	20.5	6.4	0	50.6(19.92 inches)

†See Fig. 1 and Fig. 2 for station location.

A review of literature pertaining to the high moisture zones in relation to highway problems was completed. Water table data and soil profile descriptions in selected areas of the Rapid City site were supplied by the DOT. It is hoped that additional water table data will be gathered in the spring of 1980 as a result of the interpretations of the remote sensing data.

Interpretation of the remote sensing data was accomplished using visual analysis. The CIR photography in its original film positive format was systematically and stereoscopically interpreted. Landform, drainage, soils, and vegetation were key factors which aided the delineation of potential high moisture zones. Thermal imagery was level sliced to accentuate the apparent temperature zones of interest, i.e. cool during day flights and warm during night flights. Positive prints of much of the thermal and CIR imagery have been or will be delivered to DOT personnel.

Further aspects of this study to be completed are: 1) rating each type of remote sensing data alone, in combination, at the dates flown and under the antecedent climate experienced; 2) comparing the three altitudes of data collection; and 3) evaluating the economics of any successful data, i.e. data which will expedite location of high moisture zones. Evaluation by DOT personnel of the data and interpretations has occurred and will continue throughout the project.

Results and Discussion

A major assumption inherent in the undertaking of this project was that any eventual corrective procedures initiated at the site(s) of a high moisture zone would be successfuly, preclude the replacement of highway pavement, and be more economical than the aforementioned highway repair. Experience of DOT personnel indicates that the installation of tiles to drain away excess moisture and reduce swell-shrink problems has been satisfactory. The terminus of drains could be accurately located on the thermal imagery, i.e. they were cooler than surrounding land during the day.

Several factors incurred during the first flight slightly diminished the goals of the project. As is noted in Table 1, two different thermal detectors were used, effectively removing an absolute comparison of thermal imagery between dates. The narrow range of the apparent ground temperatures preempted further data collection during the first predawn flight (305 m AGL), thus reducing a comparison of the various predawn altitudes among dates. Additionally, the distribution of rainfall did not conform to the norm for the Rapid City area (see Table 2). Notably, the data gathered during the spring flight was the result of drier than usual conditions, and a general comparison of "spring" vs. "fall" acquisition of data was not valid due to this circumstance.

The spring predawn thermal imagery was found to be of little or no use in locating wetness or shallow ground water. The basic reason for this inutility was the narrow range of the recorded apparent ground

temperatures. That these data were of no use does not preclude the potential usefulness of other spring flights. Attributable to the ineffacacy of this data was the unusual dryness of the spring.

The use of the 914 m AGL aerial data was a useful compromise between resolution and cost. It appeared, qualitatively, that important photographic or thermal contrasts were retained in the data collected at the 305 m vs. 914 m AGL flight. Further investigation on this aspect of the project will take place.

Thermal inertia, a measure of the rate of heat transfer at the interface of two dissimilar media, is a major influencing factor of heat loss at the surface of a soil. Assuming similarity in soil type, topographic aspect and slope, solar radiation, and vegetative cover, soil water content is the major controlling variable in determining the thermal inertia, thermal diffusivity (rate of conductivity and heat capacity), and evaporation. Put simply, wet soils are cooler during the day (mid-afternoon) and warmer during the evening (predawn) than are dry soils. It follows that in interpreting thermal imagery the cool apparent temperatures recorded during the mid-afternoon and the warm apparent temperatures recorded during predawn are indicators of the presence of soil moisture excluding, of course, open water. Thermal regimes are in practice, however, much more complex than has just been outlined. Soil, vegetation (growing vs. senescent), aspect, and several other confounding factors must be considered and interpreted when thermal imagery is used in a qualitative study. The

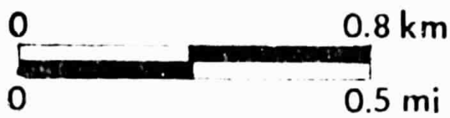
utility of CIR photography as an aid in interpreting thermal imagery becomes apparent when appraising the so-called confounding factors listed above. CIR photography does have other attributes in addition to that of an aid to thermal imagery; those attributes will become apparent in a later discussion.

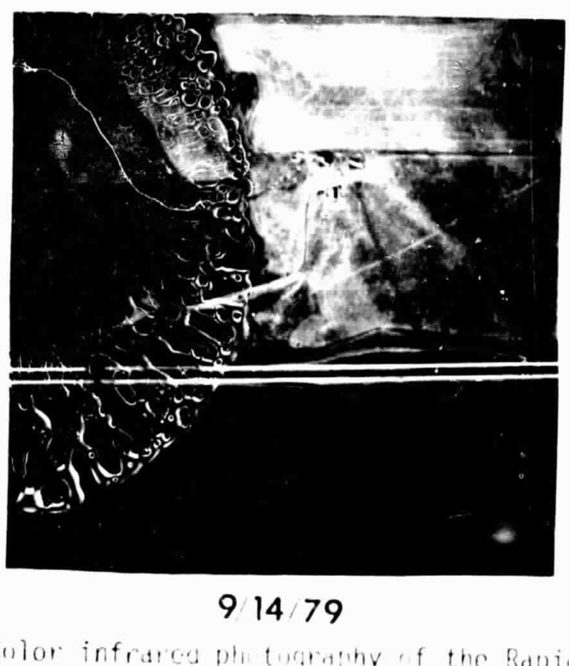
Since each set of data (thermal and CIR) was considered by itself, conditions which would be important in a quantitative, multidate investigation are negligible, e.g. solar radiation or sun angle. The objectives of this study lend themselves to a qualitative approach or, in other words, we endeavored to look only for relative differences on the landscape that can be attributable to high moisture zones. There are, however, pre-flight conditions, including the proper diurnal flight sequence, that may manifest a more useful product. Thermal data, for example, collected late in the growing season (i.e. a period of maximum downward temperature gradient) are more likely to record shallow water tables (Myers and Moore, 1972). The cycle of moisture movement within the geologic mechanism(s) (i.e. fractures, bedding planes, etc.) is conditional upon water entering or recharging the system periodically, the frequency needed to maintain a high moisture zone is dependent upon the lag time of moisture movement. Therefore, a dry or a wet year can have wide ranging effects upon the transgressive or regressive nature of the high moisture zones associated with highway break-up.

The complementary nature of thermal and CIR imagery has been identified in locating saline seeps (Dalsted et al., 1979; Worcester et al., 1979). The spectral sensitivity of CIR imagery (.51 to .80 μm) provides a discriminatory tool useful in locating salinity stressed vegetation. The vigor of vegetation drawing upon a water table relative to the vigor of moisture stressed vegetation is also discernable on CIR photography. These characteristics of CIR are useful in delineating saline seeps, springs, or high moisture zones. A build-up of salinity in high moisture zones, under a dryland system, can often be attributed to water movement through salt-laden parent materials. Therefore, salinity may be an important indicator of moisture flux, whether the salinity is expressed by a salt crust, salt tolerant vegetation, or salt stressed vegetation.

Spring and fall imagery of Rapid City site are shown in Fig. 3 and Fig. 4 (note: on thermal imagery regions of interest are cool during daytime and warm during predawn). Highway patching is shown at A in a cut section. The progression of a shallow water table is illustrated at B, from the early but less than convincing signs to the later expression both on the thermal and CIR imagery. At C and D possible shallow watertables are lcoated on the predawn imagery although the corresponding daytime imagery does have a slight indication. Overall the ease of interpretation is best achieved with the predawn imagery with assistance from the CIR. The reasoning behind this assessment lies in the fact that confounding

5/24/79





9/14/79

Figure 3. Color infrared photography of the Rapid City study site.
(Annotation is addressed in text).

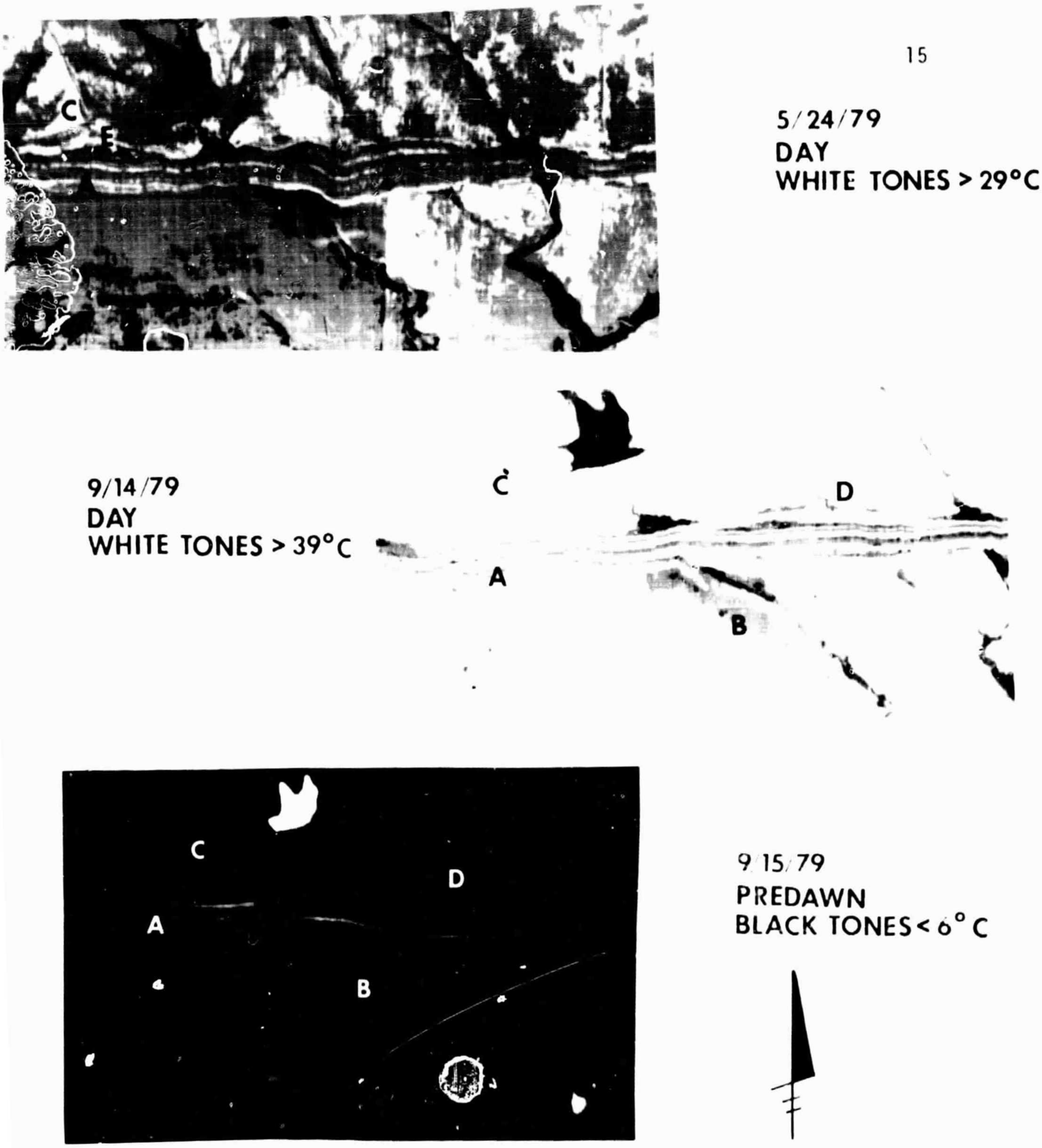


Figure 4. Thermal images of Rapid City study site. Level slices which have optimum temperature contrast are shown. Dark is cool. Approximate scale is 1:11,500 (14 cm/mile).

apparent temperatures are more prevalent on the daytime imagery and that predawn imagery has a "better" chance of recording areas of interest under the constraints of generally lesser heating of the ground in the fall.

While Fig. 3 and Fig. 4 are easily comparable by common ground features (drainage etc.), close scrutiny among dates and between predawn and daytime thermal data reveals numerous differences. For example, at E on the spring CIR imagery the slope is uniformly covered with actively growing vegetation (reddish tones); while at E on the thermal imagery there is a difference of apparent temperature, presumably relating to moisture differences. Noticeable daytime thermal differences are aligned with aspect of the northwest- to southeast-running slopes, the south facing slopes being warmer than the north facing; these differences are more pronounced on the fall imagery. These aspect differences are not apparent on the pre-dawn imagery.

The Chamberlain site has had a landslide problem. In comparison to the Rapid City site this area is steep, dissected landscape. An example of the aerial data collected over this site is shown in Figure 5. Salinity associated with members of the Pierre Formation (light tones) is more readily visualized in this area. Although the scale is different between the thermal and CIR prints, the drawn-in drainage and slope offer a means of reconciling the differences and locating the various ground features. At A and along the north ditch

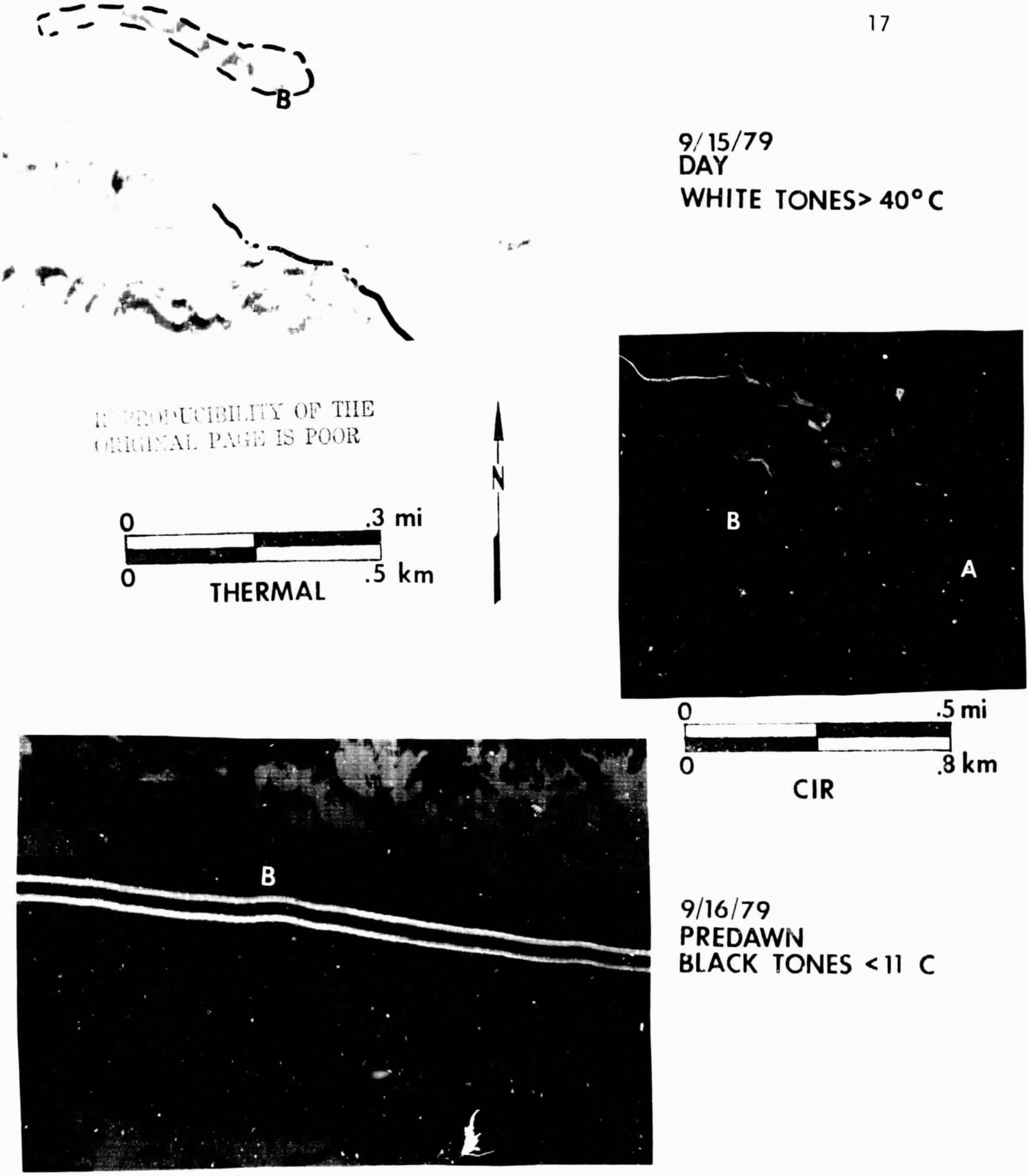


Figure 5. Thermal and CIR imagery on section of the Chamberlain study site.

salt-tolerant species are apparent on the CIR photography. The diagonals running from the highway are tile systems. At B the apparent temperature indicates seepage.

Among the imagery collected at the Chamberlain site the CIR photography appears to be the most useful medium for locating seepage and landslides. However, further interpretation is needed to fully verify the utility of CIR and thermal. This region is more complex than the Rapid City area. The exposed, barren member (dark green in Fig. 5) of the Pierre shale appears to have a high heat capacity, which differentiates it from other vegetated surfaces. This factor causes confusion in the interpretation because, even though these areas are readily recognized on the CIR imagery, the presence or absence of seepage in these areas is not easily distinguishable. Aspect and steep topography is also a problem in large differences of differential heating.

Preliminary Conclusions

It appears in the Rapid City site that the predawn fall imagery and color infrared photography provide useful information in locating high moisture zones. Further comparisons will be made among the data collected in this region. It is also tentatively planned that a drilling program will be initiated in the spring of 1980 by DOT to authenticate the reported findings.

In the Chamberlain area it appears the CIR imagery was more useful than thermal imagery for locating seepage, high moisture zones,

and potential landslide areas. Topographic and geologic complexities caused difficulties in interpreting the thermal data.

Usefulness of Results

The methods utilized in this project and the products generated appear to be practicable, practicality has yet to be fully ascertained. The speed and quick turn-around time that is possible with remote sensing is an asset especially if drilling programs and maintenance programs can be speeded by quick location of potential problem areas (i.e. high moisture zones).

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THERMAL INFRARED CENSUS OF CANADA GEESE IN SOUTH DAKOTA

By

Robert Best and Ron Fowler

INTRODUCTION

The population(s) of Canada geese using the Missouri River in South Dakota as a resting and wintering area is of particular interest to both goose managers and goose hunters. A significant portion of these Canada geese are relatively large birds and are hunted and shot by large numbers of hunters who consider the birds as trophies. Commercial or controlled goose hunting operations are becoming more common and more efficient at providing geese for hunters to shoot. Thus, goose harvest, and the potential for larger harvest, is increasing. This is cause for a concern by goose managers in both state and federal wildlife management agencies, in regard to (1) the extent of present harvest in relation to that which the goose population can withstand; (2) the proper distribution of harvest among areas, states and people; and (3) the population size in relation to potential population size or population goal based on available nesting habitat.

The only survey being conducted at the present time, which is designed to obtain information on goose population status, trend and distribution, is a weekly aerial survey during fall migration in October and November and a mid-December count of the wintering

population. The survey is conducted by five observers, each utilizing small airplanes from which to make visual estimates of ducks and geese on a particular segment of the Missouri River. The trend of population distribution is toward fewer and larger concentrations due primarily to increased concentration and availability of food as in controlled goose hunting areas. Accurate estimates of numbers of birds in these concentrations, and thus the entire population, are becoming more difficult, or impossible, to make. Photographic spot checks of visual estimates have indicated visual estimates may be 50-75 percent lower than actual numbers of birds in a concentration. Also, the percent error probably varies among observers thereby resulting in inconsistent estimates. Another source of error in estimating total number of birds using a segment of the Missouri River is the number of birds which are feeding in areas away from the Missouri River during the time of the flight and are not found and counted.

A survey method is needed to reduce large errors being made during counts of geese on the Missouri River in South Dakota to within ±10 percent of the actual number. The method should allow counting of individual birds, or at least a more accurate means of estimating numbers other than by aerial visual estimates made at the time of the flight. The method should also provide for counting or recording numbers of birds at a time of day when all birds using a segment of the Missouri River are on the water and not out feeding. This means that the method should have the flexibility of allowing

the survey to be conducted during night-time or day-time hours. Geese normally rest on water at night and do not go out to feed except possibly during moonlit nights, and late dusk and early dawn hours.

A goose population survey method which allows accurate determination of the number of birds in a population could have considerable impact on goose management and goose hunting if the magnitude of error in current survey methods is as great as found during spot checks. The effectiveness of population management improves as the accuracy of population data increases. Not only will the welfare of the population be insured by more accurate regulation of harvest, but also hunting seasons can be designed to provide both a maximum amount of recreational opportunity and a more equitable distribution of harvest.

Since errors apparently being made during the present survey are causing underestimates of total population size, an accurate estimate of the population would probably allow a more liberal season in terms of increased recreational opportunity and increased harvest by hunters. Additional indirect benefits would be increased license sales, the money from which goes back to wildlife management and research, and increased money in the state's economy due to more hunters and more hunting-related expenditures.

Thermal infrared imagery has been used, with varying degrees of success, for the census of white-tailed deer (Croon et al. 1968, McCullough et al. 1968, Graves et al. 1972); elk, moose and deer

(Wride and Baker 1977); harp seals (Lavigne and Ronald 1975); and polar bears (Brooks 1970). Most animals have insulating integuments which minimize heat loss and reduce the temperature differential with the environment which results in a lack of thermal contrast. Preliminary results indicate that Canada geese may have a high radiant temperature relative to ambient air which might provide sufficient contrast for their interpretation on thermal imagery.

The geese are concentrated on the mainstem reservoirs of the Missouri River in central South Dakota. The water will provide a relatively constant background temperature with an emissivity of approximately 1. It will be necessary to make counts during the night when feeding geese have returned for the night.

Apparent temperature measurement, of a wild Canada goose, provided by S. D. Department of Game, Fish and Parks, were made with a Barne's Precision Radiation Thermometer* (PRT). The data indicate that the apparent temperature of the back of the goose ranged from 6-12° C above the ambient temperature. Temperature measurements made on domestic ducks showed slightly lower but similar results.

Assuming that the apparent temperature of the goose is approximately 6° C above the air temperature and that the surface water temperature is approximately 1° C then it appears feasible that

*Inclusion in this report of registered trade names or trademarks does not constitute an endorsement by the authors or the Remote Sensing Institute.

interpretable aerial thermography could be collected when ambient temperatures are less than -9° C or greater than -1° C. If data are collected within these restraints geese will have an apparent temperature lower than the water background in the first case and warmer in the second. The acceptable ambient temperature range will vary with water temperature.

The objectives of this project are to: (1) develop operational procedures to use predawn aerial thermography to census Canada geese (*Branta canadensis*), (2) determine which of two wavelength detectors (4.5-5.5 μm, 8.7-11.5 μm) will provide maximum apparent temperature contrast, (3) evaluate optimal altitude-resolution parameters for data collection, (4) establish an ambient temperature range at which procedures will be most effective, (5) determine the effect of climatic and microclimatic factors including: cloud cover, humidity, and wind velocity on data collection, (6) develop an emperical relationship between the thermal anomalies produced by the geese and goose numbers, (7) develop operational procedures to obtain contiguous aerial thermography over water resting areas, (8) measure the approximate emissivity of goose skin and features, (9) estimate costs for conducting survey annually.

Heat Loss by Canada Geese

Heat loss from two subspecies of Canada geese at varying environmental temperatures (Birkebak et al. 1966) and the effect of heat loss on the distribution of Canada geese (LeFebore and Raveling

1967) have been studied. The calculated heat loss at varying environmental temperatures for adult male *Branta canadensis maxima* and *B.c. parvipes* is presented in Figure 1. The figure shows a rapidly increasing heat loss with decreasing environmental temperature. The regression lines coverage at 40° C which is very close to the 40.8° C rectal goose temperature reported by Benedict and Lee (1937). There would be minimal heat loss to the environment when the body temperature equals the environmental temperature. Benedict and Lee (1937) reported that most geese show a basal metabolism at 28° C while there was a marked increase in metabolism at temperatures of 10° C and less. Energy balance and factors affecting heat loss from white-tailed deer (Moen 1968, 1966) ruffed grouse (Brander 1965) and numerous domestic animals (Bond et al. 19[illegible], Blaxter and Wainman 1964, and Clayton and Boyd 1964) have also been studied.

The major factors contributing to heat loss from a goose are conduction, convection, radiation and evaporation. The temperature profile near the skin is determined solely by conduction (Birkeback et al. 1966). A major proportion of the sensible (non-evaporative) heat loss from the back of a Canada goose resting on water, can be attributed to a combination of convection and radiation. The radiated component, which can be measured with remote sensors, should be the most significant, because the environment acts as an infinite heat sink. Latent (evaporative) heat loss is insignificant at low temperatures (Salt and Zeuthen 1960). Heat loss from the bill will

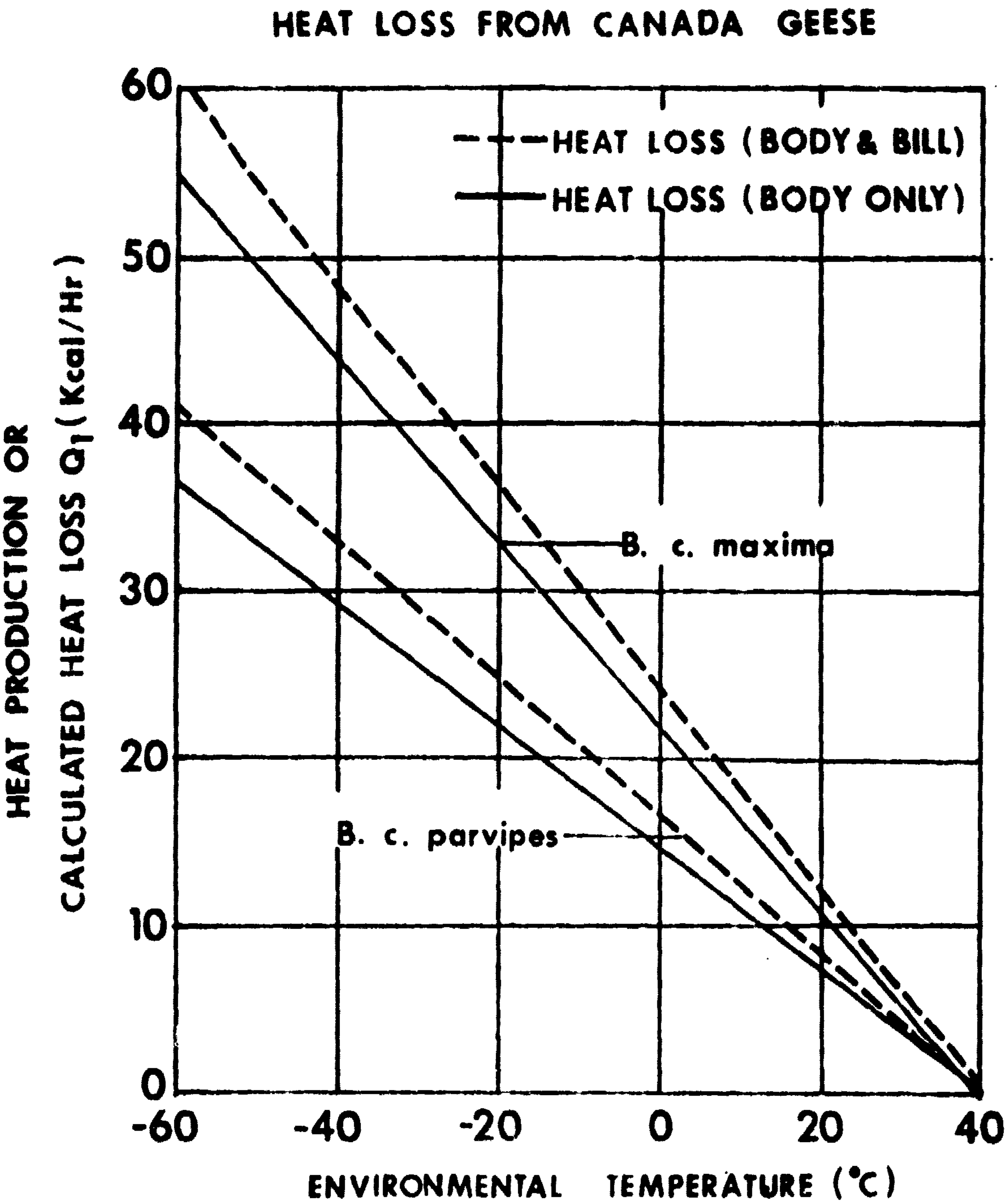

Figure 1. Heat loss from Canada geese as a function environmental temperature (adapted from Birkebak et al. 1966).

be negligible because resting or sleeping geese generally place their bill under their wing during cold weather.

The energy emitted from the surface of a goose depends not only on the temperature of the feathers, but also the emissivity of the surface as expressed by the Stephan-Boltzman Law (Campbell 1977):

$$R = \varepsilon \sigma T^4 \qquad [1]$$

where:

R = energy emitted by non-blackbody W m^{-2}

ε = emissivity of the surface

σ = Stephan-Boltzman constant 5.67 x 10^{-8} W m^{-2} K^4

T = absolute temperature in °K

Most surfaces radiate slightly less than a perfect radiator (blackbody). Hammel (1956) measured the emissivity of the integument of 10 species of artic birds and mammals and found that within the experimental error, the emissivities were not measurably different than 1. Hammel concluded that there was no advantage in heat conservation for animals with white integument. It was shown that animals which were white in visible wavelengths were not necessarily "white" in the thermal infrared wavelengths. Svihla (1956) found similar results in an experiment with dyed rats.

PROCEDURES

The emissivity of Canada geese and the apparent temperature of live Canada geese at varying environmental temperatures were

measured to supplement the collection of aerial thermography. The specific methodology used in each situation is as follows.

Measurement of Thermal Infrared Emissivity

Emissivity values of unpreserved goose integuments from 2 subspecies of Canada geese (*Branta candensis interior* and *B.c. hutchinsonii*) and adult and immature snow and blue geese (*Anser caerulescens*) were calculated from measurements made with a Barnes Precision Radiation Thermometer. Skins were removed from freshly killed geese and frozen until measurements were made. Skins were removed from the freezer to allow their sensible temperature to equilibrate with environmental temperatures. All measurements were made in a shaded area under cool clear skies.

Two methods were used to estimate the emissivity. A rough estimate was made by rationing the apparent temperature (°K) to the fourth power. A second more precise technique which accounts for the effects of background radiation was also used. The technique developed by Fuchs and Tanner (1966) for infrared thermometry of vegetation is based on a form of the Stephan-Boltzman Law (equation [1]) which considers background radiance effects.

$$R_b = \varepsilon\sigma T^4 + (1-\varepsilon)B^* \qquad [2]$$

where:

R_b = radiation received by the sensor

$(1-\varepsilon)B^*$ = incoming thermal infrared reflected by the surface

B^* = background radiance

In this method the apparent temperature of an aluminum plate for which the emissivity is known is measured with the PRT. The actual temperature is measured with a digital thermometer and thermocouples embedded in the plate. The background radiation is then calculated by solving equation [2] for background radiance (B*).

$$B^* = \frac{R_b - \epsilon\sigma T^4}{1-\epsilon} \qquad [3]$$

where:

$R_b = \sigma T^4$ (T is apparent temperature measured by PRT in °K)

Measurements of the apparent temperature of the goose skins were made with the PRT. The actual temperature was measured with the PRT by placing the goose skin under a speciman chamber lined with aluminum foil, which simulates a blackbody cavity. The emissivity was then calculated by solving equation [2] for ϵ.

$$\epsilon = \frac{R_b - B^*}{\sigma T^4 - B^*} \qquad [4]$$

where:

$R_b = \sigma T^4$ (T is apparent temperature measured by PRT in °K)

σ = Stephan-Boltzman constant 5.67×10^{-8} W m^{-2} K^4

T^4 = actual temperature °K measured with PRT under blackbody cavity

B* = background radiance

Five measurements of apparent and actual temperature were made on each of 2 different skins for each type of goose. An average of background radiance calculated from measurements made at regular intervals during the measurement of goose skins was used in the calculations. Statistical means and standard deviations of emissivities were calculated for each individual skin and goose type. Analysis of variance was used to determine if statistically significant emissivity differences occurred between geese. Statistical analyses were performed using the Statistical Analysis System (SAS) procedures (Barr et al. 1976).

Measurement of Apparent Temperature of Canada Geese at Different Environmental Temperatures

The apparent temperature of six hand-reared pinioned Canada geese was measured with a radiation thermometer (PRT). Five duplicate measurements of each goose were made at environmental temperatures ranging from -25 to 15° C. All measurements were made under cool clear skies. The background radiation was estimated from PRT measurements of an aluminum plate with a known emissivity in which thermocouples have been embedded to determine actual temperature. Relative humidity was calculated from wet and dry bulb temperatures measured with a sling psychrometer. Mean apparent temperatures of each of the six geese were plotted against environmental temperatures. Linear regression analysis will be used to statistically model the relationship.

Collection of Aerial Thermography

Aerial thermography will be collected 5 times during the project. Aerial thermography was collected during the day and at night on 16 November 1979. A brief description of the characteristics of the scanner and the detectors that will be used and its operations are presented as part of this report. The first 4 data collections will be used to determine project feasibility and optimal conditions for data collection. These four flights will be flown as two missions, each with a day-time and predawn data collection over a high density of geese in a restricted area. Data will be collected at altitudes of 1000 ft., 1500 ft., and 2500 ft. AGL (above ground level) during each flight. Both the photo voltaic (4.5-5.5 μm) and trimetal (8.7-11.5 μm) detectors will be used during the first day-time/pre-dawn mission. The detector which produces the best results will be used during the following flights.

Thermal data will be processed into a photographic format which will be scaled to base maps and aerial photographs. The thermal data will be 'level sliced' into equal temperature increments during the processing. The 'level slicing' process divides the voltage signal from the scanner into 6 equal voltage increments which produced discrete gray tones on the photographic imagery. Each of the grey levels represent an equal apparent temperature increment. Any one or more consecutive levels can be further divided into 6 more levels to provide the required apparent temperature resolution.

Aerial photography (70 mm) will be collected concurrently with thermal data during each day-time flight. These photos will be used to develop the empirical number/area relationship for geese. The Department of Game, Fish, and Parks will provide estimates of the number of geese in the area, by trained observers in small aircraft. A comparative analysis of the goose numbers from the trained observer's aerial photographs, and the thermal data will be made.

Collateral ground data including water temperature, relative humidity, wind velocity and cloud cover conditions will be collected during both day-time and predawn data collection.

The data will be used to formulate optimal conditions for an operational flight. The final data collection mission will be made during the first 2 weeks of January 1980. It will cover major goose concentrations along the Missouri River in South Dakota. An estimate of total number of geese present will be provided to the Department of Game, Fish, and Parks. This flight will be used to determine the cost/benefit of a continuing operation activity.

Operation of Thermal Scanner

A thermal-scanning system is used to convert thermal emittance as viewed with a detector and recorded electronically, into an image which can be used for interpretation. Forward motion of the aircraft and rotation of a mirror produce a series of data lines which can be reassembled into an image similar to a traditional photographic image. The actual data recorded are voltages whose amplitudes are

proportional to the incoming energy levels. The instantaneous field of view, spectral sensitivity, thermal resolution, detector response time, etc., are all system properties which vary from scanner to scanner.

Operating parameters such as adjustment of blackbody references and determination of the appropriate V/H (Velocity to Height ratio) of the aircraft are operator controlled. Certain scanners have internal blackbodies which are used to relate the input energy to output voltages. The incoming radiation signals are alternately compared with known energy reference sources. These known energy references are adjusted to bracket the anticipated energy level of the radiating surface being measured. A comparison of these known energy levels to the measured levels allows the interpreter to determine quantitatively the incoming energy levels with subsequent calibration to equivalent blackbody temperatures. Since the scanner mirror rotates at a constant speed and has a fixed geometry, the V/H must be determined and adjusted to relate aircraft motion with film speed during processing to produce continuous coverage of the land surface in the resultant image.

Characteristics of Scanner Used for Data Collection

Trimetal (Hg:Cd:Te:) and photovoltaic (InSb) detectors cooled to liquid nitrogen temperatures will be used to detect the incoming thermal radiation. The spectral response to the filtered signal and the detectors are approximately 8.7 - 11.5 μm and 4.4 - 5.5 μm,

respectively. The spatial resolution of the Daedalus scanner is 1.6 milliradian. As a function of aircraft altitude, this corresponds to 0.48 m (1.6 ft) resolution cell per 305 m (1000 ft) of aircraft altitude. The operational range of the analog voltage signal is from +2.0 to -2.0 volts. These voltage extremes are used for the blackbody settings which are adjustable and can be determined by viewing the range of signal on an oscilliscope for the terrain to be recorded. These adjustments normally require a preliminary aircraft pass over the area to be imaged for determination of the appropriate blackbody settings. The thermal resolution of the system is approximately 0.2 degrees Celsius (C) with the absolute accuracy of the blackbodies quoted at ±0.5 C.

RESULTS AND DISCUSSION

The mean emissivities of six types of geese ranged from .957 to .966 (Table 1). Statistical analysis of variance indicated that there was no statistically significant emissivity difference between geese at the .90 confidence level. Based on these results the mean emissivity for all geese is .962 + .017 (95% confidence interval). Several authors (Hamilton, 1939 and Hesse et al. 1952) have hypothesized that arctic mammals and birds may have a reduced thermal emittance as a result of their white coloration. The results of the study contradict this hypothesis. The adult snow goose which is pure

Table 1. Infrared emissivities of central flyway geese

Species	Visible Color	Mean Emissivity
Canada goose *(Branta canadensis interior)*	dark grey	.962
Canada goose *(B.c. hutchinsonii)*	dark grey	.966
Adult snow goose *(Anser caerulescens)*	white	.963
Immature snow goose	light grey	.959
Adult blue goose *(Anser caerulescens)*	grey	.964
Immature blue goose	grey	.957

grand mean* .962 ± .017

* 95% confidence interval

white has the same infrared emissivity as the very dark colored Canada goose and both are very close to that of a blackbody radiator. There would be an advantage in heat conservation, had the emissivity been very low, because radiant heat loss is proportional to emissivity. Emissivity values calculated without consideration of background radiation ranged from .98 to .99 which would correspond very closely with emissivity measureme ts of arctic mammals and willow ptarmigan (*Lagopus lagopus*) made by Hammell (1956). The effects of background radiation are not considered in the technique developed by Hardy (1934) that was used by Hammel.

The relationship of the apparent temperature of Canada geese to varying environmental temperature is illustrated in Figure 2. The apparent temperature of Canada geese, must be known in order to determine if sufficient temperature differences are present for data collection. This can be calculated using the following statistical model:

$$Y = .653X + 6.803$$

where:

Y = apparent temperature of geese

X = ambient temperature.

The model accounts for 87% of the variance in the data and will be further refined to reflect differences at other environmental temperatures. Preliminary results indicate that apparent temperature differences of ≥5° C between the geese and the background will be sufficient to discern the geese on thermography collected and processed with the equipment used in this project. In this area the geese will be resting on the reservoir which limits the background to open water or ice during late season.

The apparent temperature difference between the Canada geese and the ambient temperature is not constant and increases with decreasing ambient temperatures (Figure 3). This relationship must be considered in flight planning and may be calculated from the following statistical model.

$$Y = .315X + 6.699$$

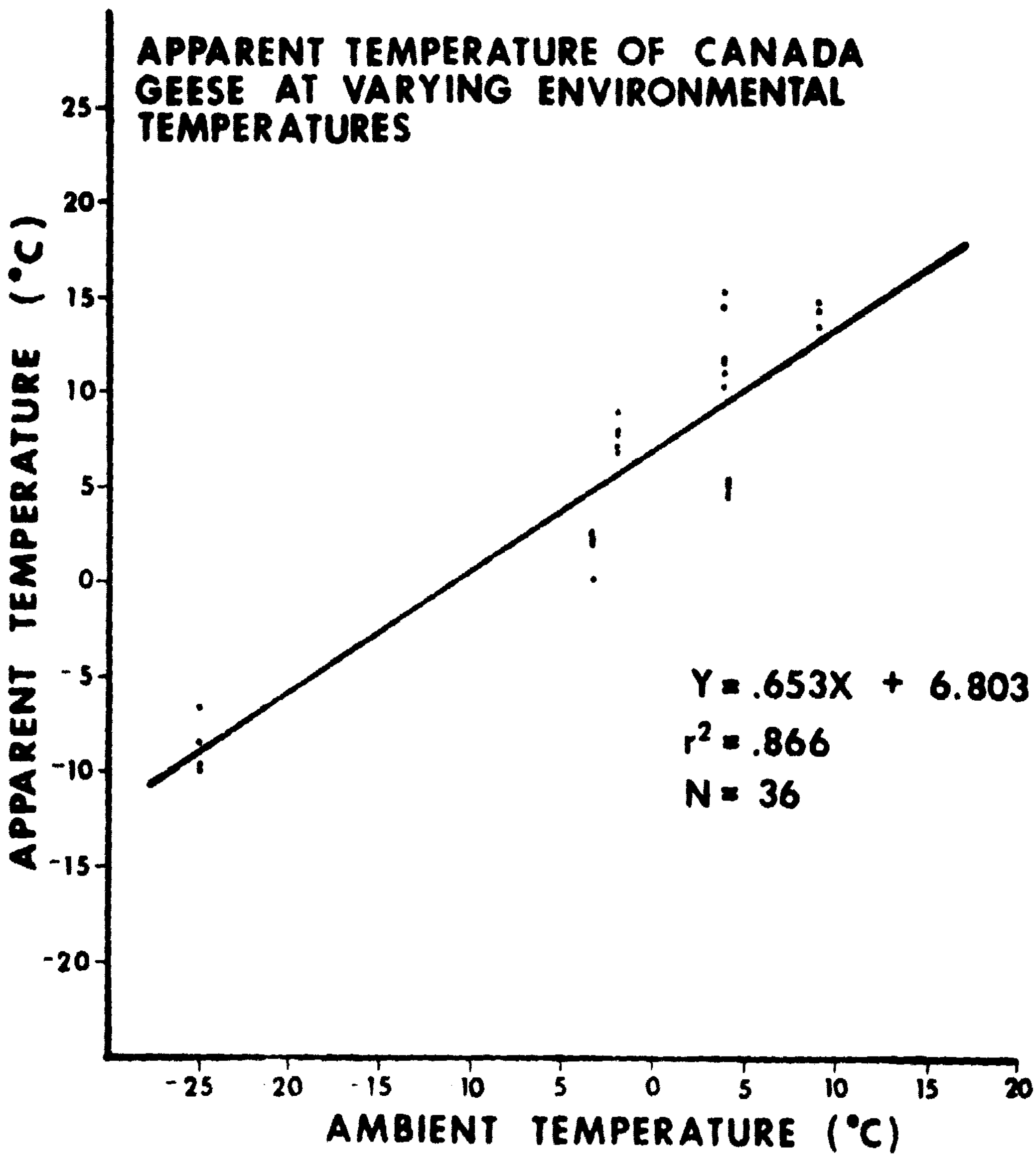

Figure 2. Relationship of the apparent temperature of Canada geese to varying environmental temperature.

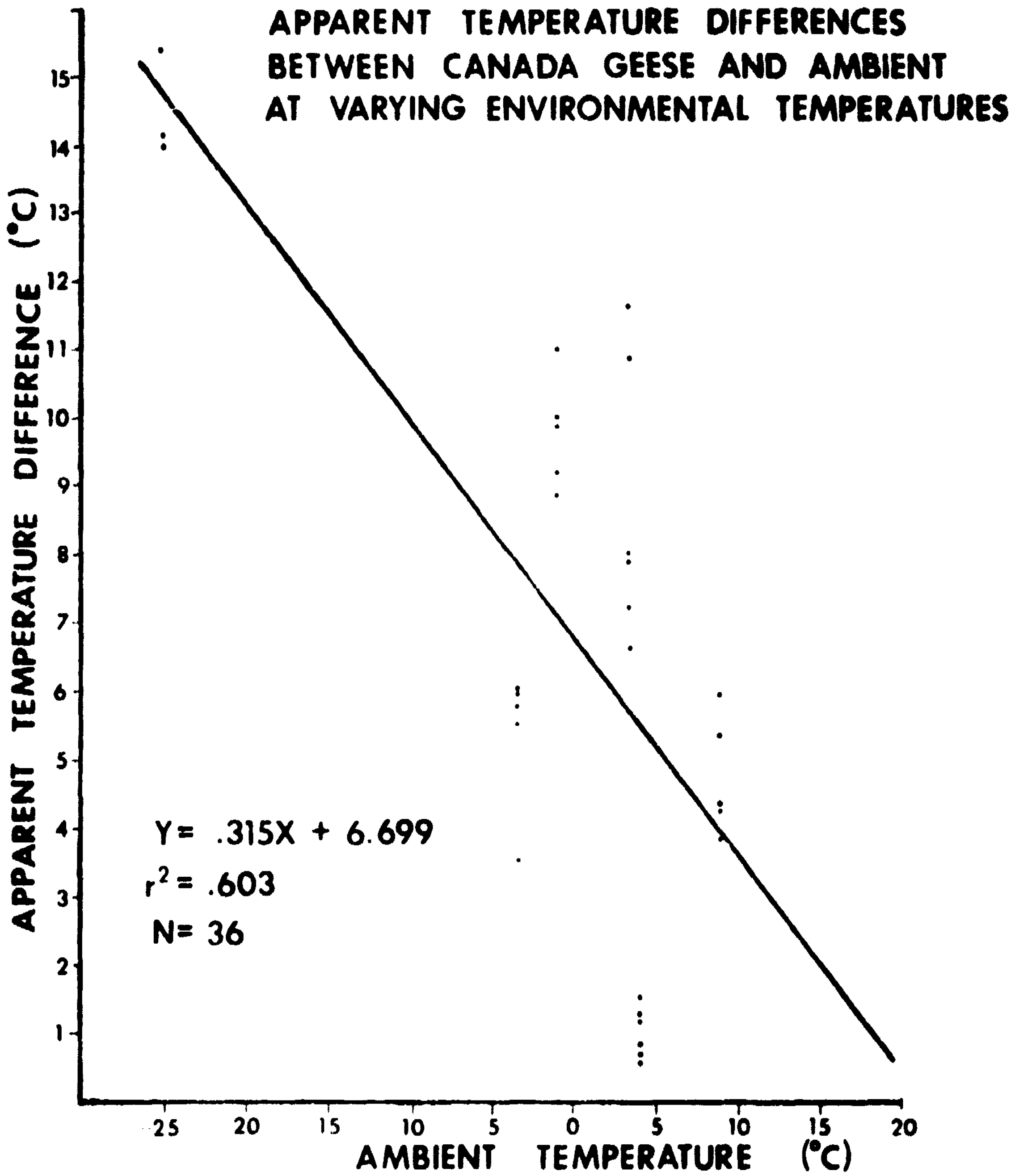

Figure 3. Relationship of apparent temperature difference between Canada geese and ambient at varying environmental temperatures.

where:

Y = apparent temperature difference between goose and ambient

X = ambient temperature

This model accounts for 60% of the variance in the data. This model will be refined during the rest of the project as additional data are collected.

The ambient temperature ranged from 19° C on the ground to 16° C at 2500' AGL during the daylight mission and was 8° C on the ground with a 10° C inversion at altitude during the night mission. The reservoir temperature was 7° C during both missions. Based on apparent temperature measurements on captive geese sufficient apparent temperature contrast was present during the daylight mission while conditions were marginal during the night mission. The effects of temperature inversion are unknown.

The tone (lightness or darkness) on thermography is relative to the apparent temperatures of scene features. Thermal imagery can be produced in either an analog or digital photographic format. The continuous tones on the analog imagery (Figure 4) represent a continuous temperature range.

This imagery may be used to determine the presence of geese but has limited contrast depending on the temperature differences of scene features. The exact location and density of geese can be identified on Figure 5 which is a mosaic of black and white panchromatic aerial photography collected concurrently with the thermal

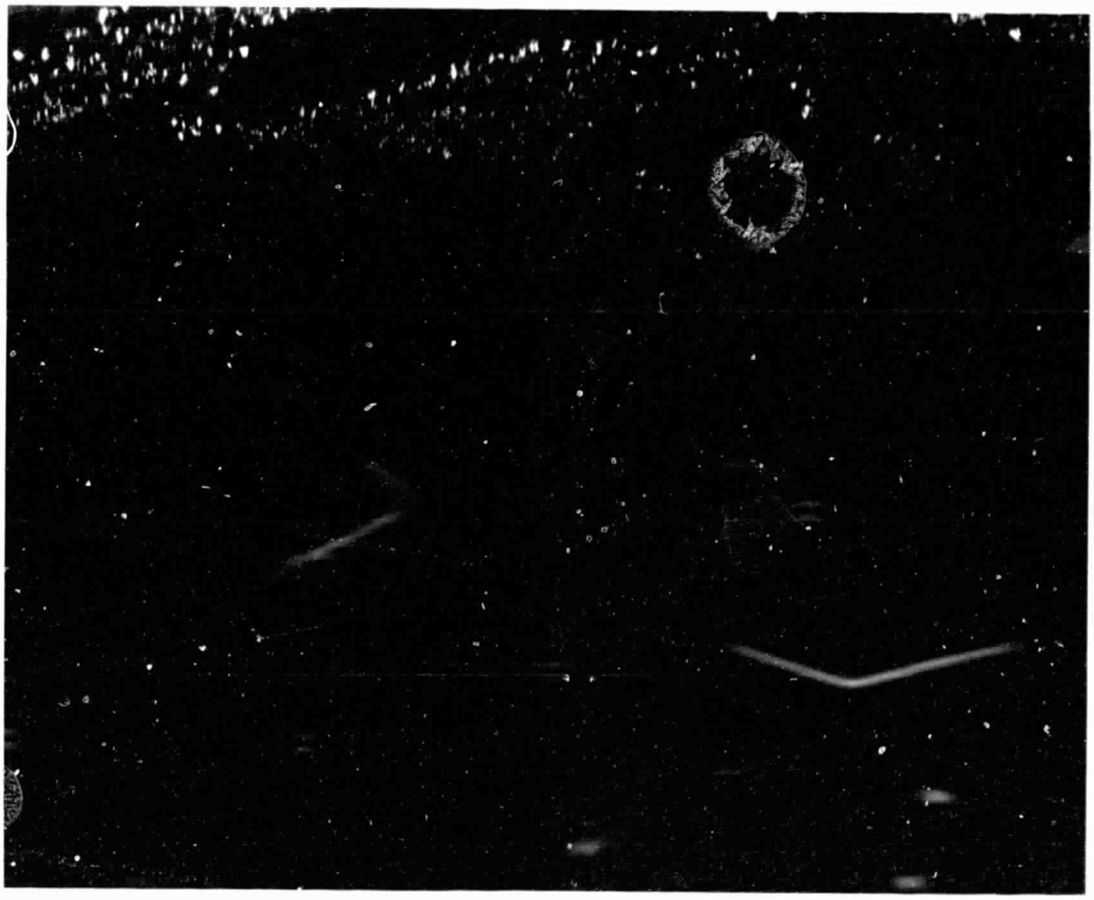

Figure 4. Positive print of analog thermography collected with trimetal detector at 1500' ft. AGL.

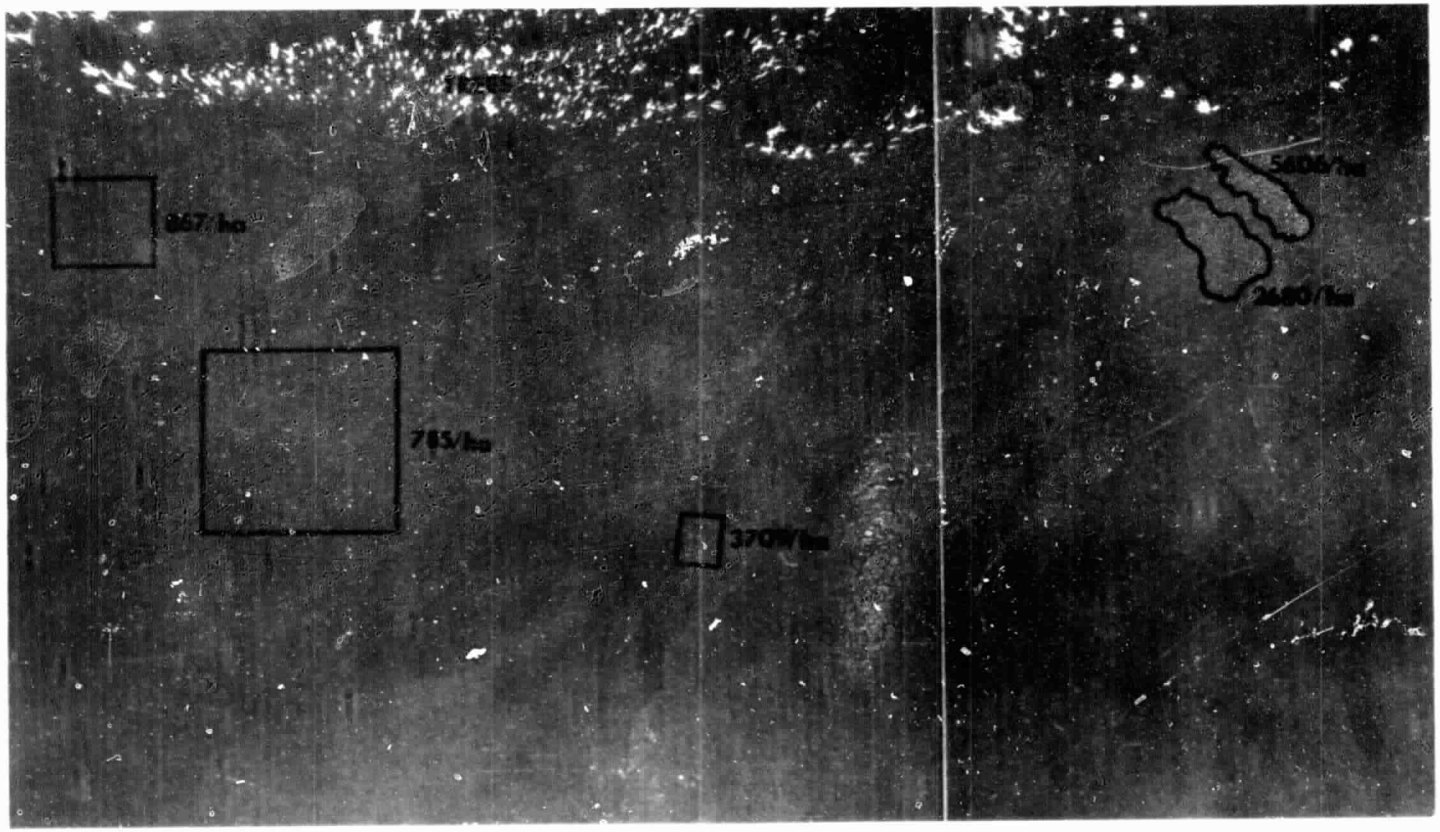

Figure 5. Mosaic of black and white panchromatic aerial photography collected concurrently with aerial thermography. Density of geese are reported as number of geese per hectare.

data as ground truth for developing the technique. The densities of geese in the figure are reported in numbers of geese per hectare.

The thermal data can also be processed into a digital format with 6 equal discreet apparent temperature increments between the blackbody temperatures (Figure 6). The breaks between temperature increments can more easily be delineated in the digital format. In this case the geese cannot be distinguished on the full range digital data which indicates that the apparent temperature of the geese is within 1.7° C of the apparent temperature of the background and both fall in the same temperature increment.

One or more of these temperature increments can be "sliced" into another 6 equal levels with a subsequent increase in temperature resolution (Figure 7). In Figure 7 the 9.7-11.3° C temperature level of Figure 6 has been sliced. The apparent temperature increments in Figure 7 are 0.3° C as compared to the 1.7° C of the full range digital data in Figure 6. The geese now fall in a temperature level different from the background and can be identified. The geese appear in the 10.5-10.8° C apparent temperature range in these data. Single levels, isolevels, can be printed for easier delineation (Figure 8).

The position of the temperature levels relative to the blackbody temperatures can be shifted slightly during "fixed" processing which produces temperature increments with no reference to the blackbodies. This technique can be used to include geese in a single

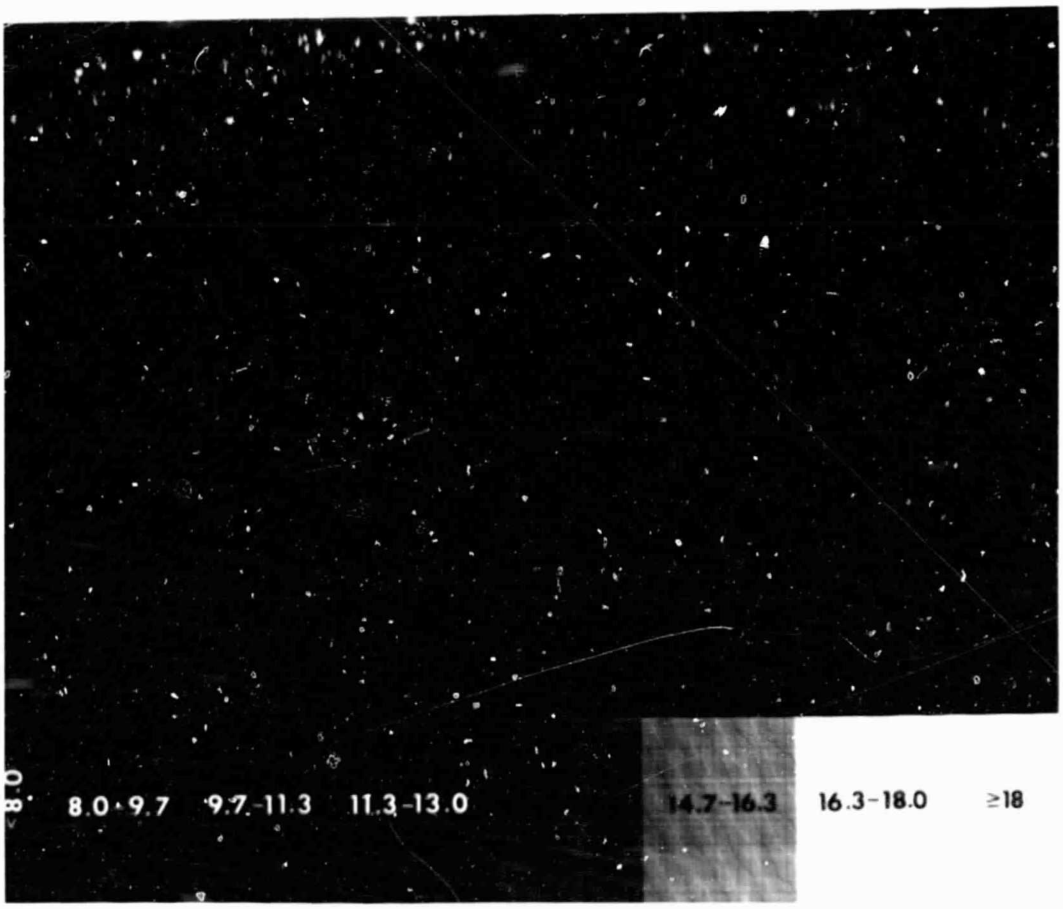

Figure 6. Full range digital print of aerial thermography collected with trimetal detector at 1500 ft. AGL.

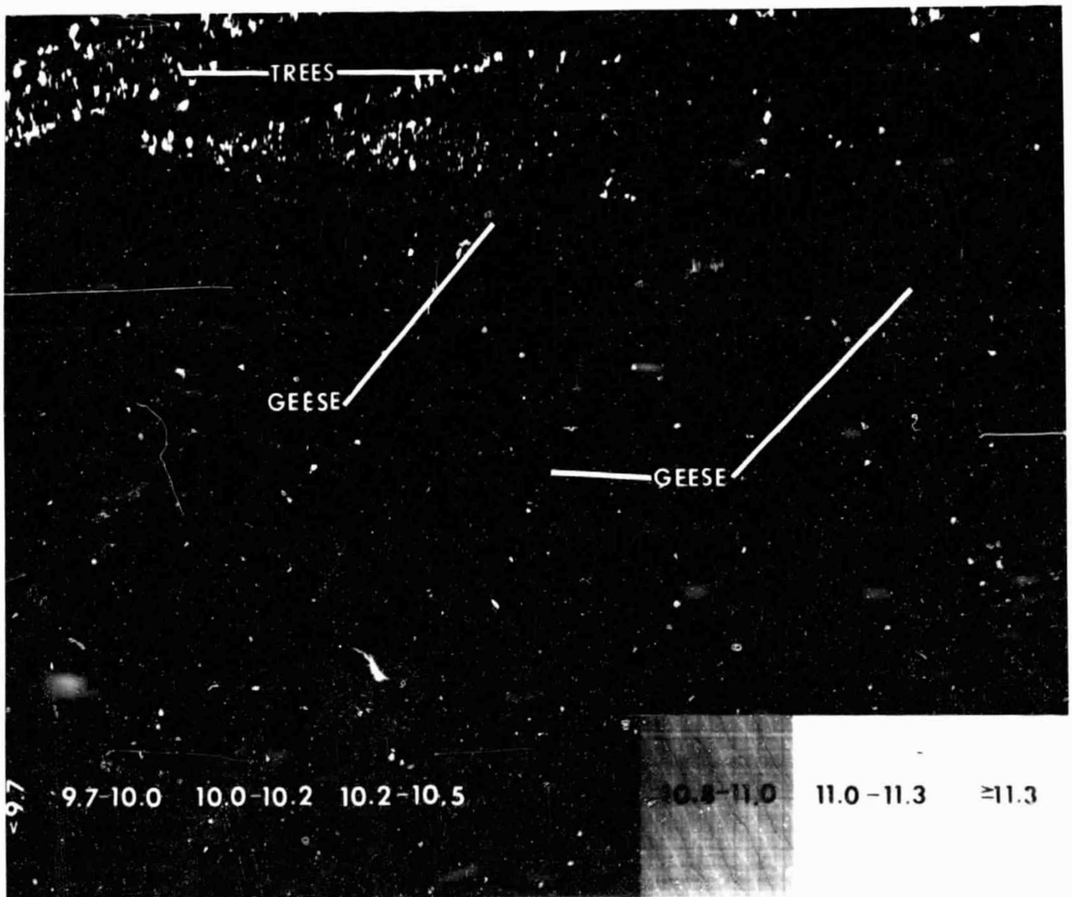

Figure 7. Six level density slice of 9.7-11.3^0 C apparent temperature increment from the full range digital aerial thermography.

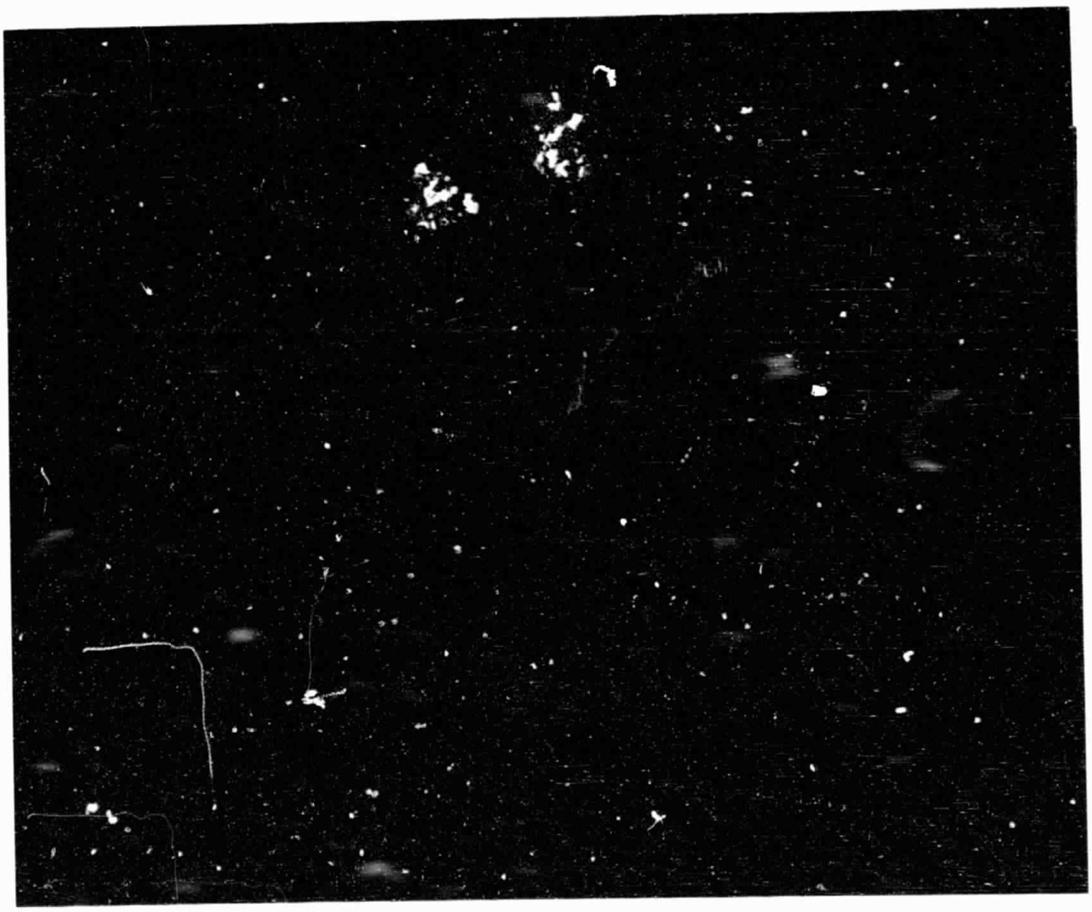

Figure 8. Positive print of isolevel 10.5-10.8^{o} C from the 9.7-11.3^{o} C level slice of aerial thermography.

level which may have slightly higher or lower apparent temperatures than the majority of geese and may have fallen in another level (Figure 9). The lower densities of geese are more apparent in Figure 9.

The imagery selected for illustrations in this report were collected with the trimetal dector at an altitude of 1500 ft. AGL. The spatial resolution of the scanner at this altitude is approximately 2.4 ft. which is the principle reason why very low densities of geese cannot be resolved on the imagery. The resolution of the thermography is inversely proportional to the altitude. Geese could not be resolved on the 2500 ft. AGL thermography. The resolution at 1000' AGL is 1.6 ft. and it appears that low densities of geese may be more identifiable of that imagery. However, this cannot be substantiated because of the absence of ground truth due to a malfunction of cameras during data collection at this altitude. The data will be evaluated after additional test flights.

The geese could not be distinguished from the background at any altitude on thermography collected with the photovotaic detector. The signal to noise ratio was very low resulting in data with very low temperature contrasts. This may be attributed to the very strong thermal absolution band due to water vapor that begins at about 5 μm (Figure 10). There is also some absorbance by carbon monoxide. The effects of ozone absorbtion would be minimal on the trimetal detector because of the low concentrations of ozone at the altitude flown.

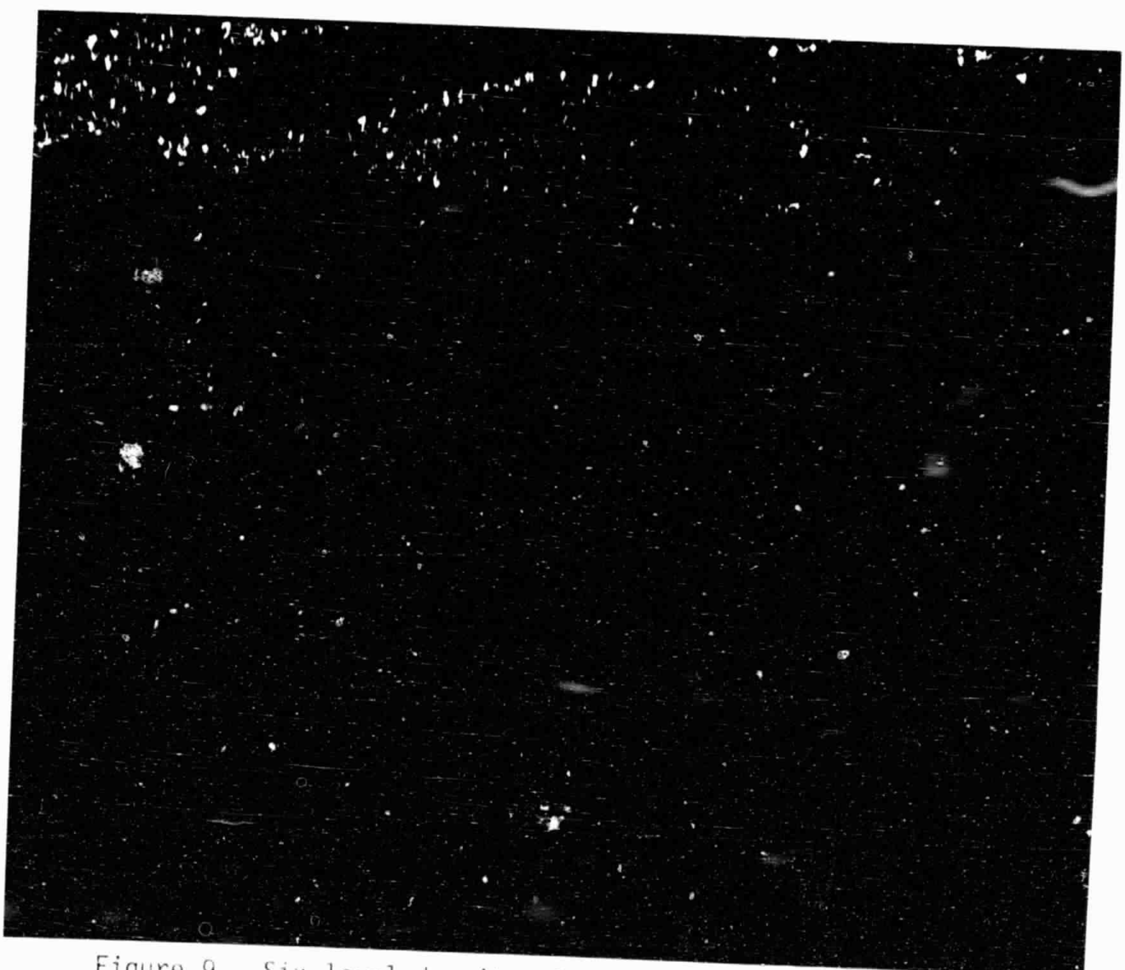

Figure 9. Six level density slice processed in a fixed mode with no reference to blackbodies.

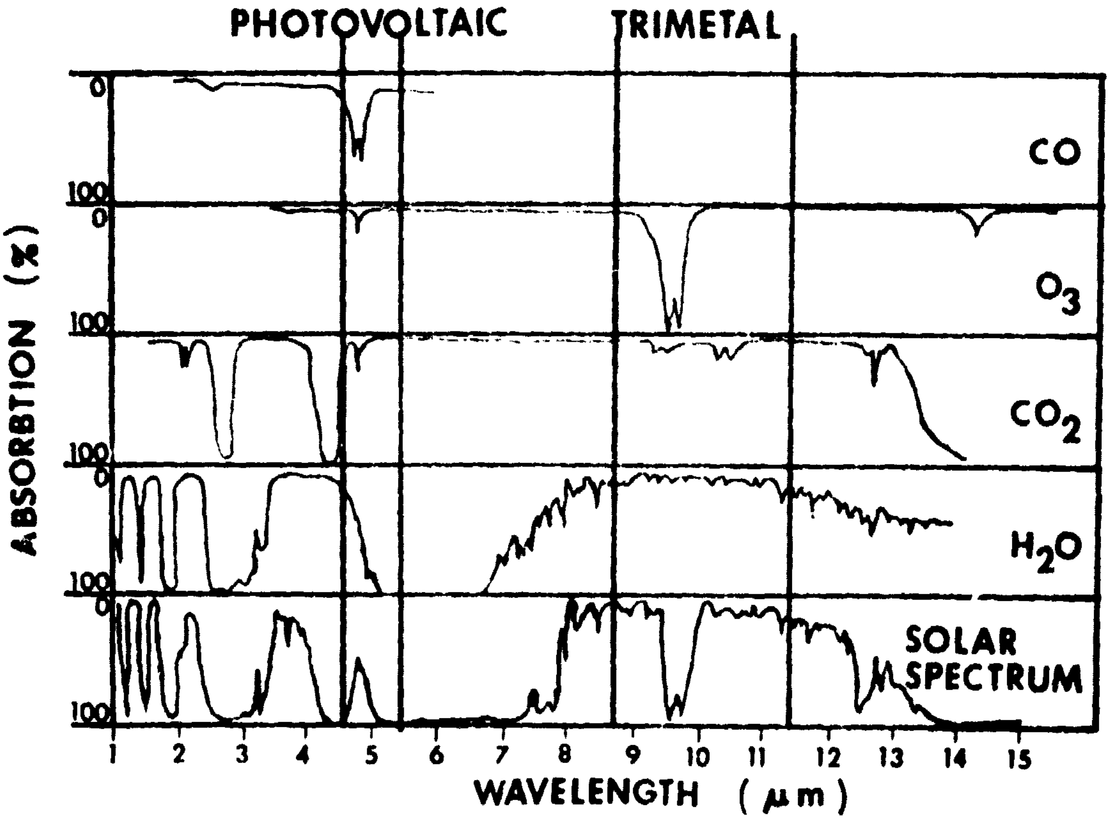

Figure 10. Thermal absorbtion of atmospheric constituent adapted from Wolfe (1965).

SUMMARY AND CONCLUSIONS

Preliminary results indicate that an operational technique for censusing Canada geese on thermal imagery may be feasible. Geese could be identified on aerial thermography when their apparent temperatures were within 1.7° C of the background temperature. The spatial resolution of the thermal scanner that is being used will limit the altitude for data collection to 1500 ft. AGL or less. The photovoltaic detector does not provide thermal data with sufficient temperature contrasts to identify geese under the environmental conditions experienced during the test flight. The trimetal detector will be used for data collection while the geese are resting on the reservoir. The emissivity of Canada geese of .962 was measured with no significant difference between subspecies of Canada geese or between species of other central flyway geese. Statistical models to predict apparent goose temperatures and apparent temperature differences at varying environmental temperatures will be refined as additional data are collected at different temperatures. Additional test flights will be made at low ambient temperatures in order to define environmental constraints for data collection. If the techniques can be perfected it will result in a more accurate regulation of harvest. Hunting seasons can be designed to provide both maximum recreational opportunity and more equitable distribution of harvest if the technique provides accurate population data. The method will replace current methods which may have considerable error.

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APPLICATION OF REMOTE SENSING TECHNIQUES FOR DETECTING DUTCH ELM DISEASE IN URBAN ENVIRONMENTS

INTRODUCTION

Dutch elm disease is a disease fatal to most elm species but especially the American elm (*Ulmus americana*). The disease is caused by a fungus (*Cerotocystis ulmi*) which invades and grows in the water conducting vessels of elm. The disease is generally transmitted by the European elm bark beetle (*Scolytus multistriatus*) and the native elm bark beetle (*Hylurgopinus rufipes*). The beetles overwinter as larvae and adults under the bark of dead or dying elms. In the spring the emerging adult beetles, contaminated with fungus spores, fly to dead or dying trees to reproduce and then on to healthy trees to feed. It is at this point that the infection is spread.

Sanitation by removal and destruction of dead and dying elm is the only way to slow disease spread within an elm population. Prompt identification and destruction can reduce losses to levels where severe economic impact is minimized. The Department of Game Fish and Parks estimated that 28,000 elms were lost to Dutch elm disease in 1978. The economic loss, including removal of dead trees exceeded $22 million.

The severity of the tree loss problem has prompted investigations to test the feasibility of using remote sensing techniques for early detection of Dutch elm disease. French and Meyer (1966) were among the first to use low altitude color infrared aerial photography to detect diseased trees. Waltz (1969) and La Perriere and Howard (1971) also recognized the utility of color infrared photography for detection of diseased trees. The investigators determined the disease is easiest to

detect and has the highest incidence in early July. It is also recommended that a survey in late August would also be useful in detecting trees infected by second generation adult beetles.

The concensus of the investigators was that aerial photography was a fast, low cost survey method. Accuracy of detection ranged from 50-70 percent. Accuracy was influenced by difficulty of species identification, difficulty in discriminating the target disease from other kinds of moisture stress-inducing situations, difficulty in mapping locations of infected trees and coordinating the photo with the ground situation. It is expected accuracy can be improved in the proposed project because many of the previous investigations were performed in a natural forest rather than an urban forest. In a normal urban environment it should be easier to identify species because the crown density will be less therefore allowing clear identification of individual trees.

The city of Watertown with the assistance of the South Dakota Department of Game, Fish and Parks, Division of Forestry has taken significant steps that should facilitate Dutch elm disease detection. Over the past year the Watertown city forester, with the assistance of the South Dakota Division of Forestry, has mapped and inventoried by species all trees on most public land and street boulevards. The inventory was performed to simplify the annual ground surveys necessary to identify diseased trees on public land.

The problem still facing the city of Watertown is how to identify early diseased elms on private property as well as to monitor for disease in the already identified elms on public property. The city has an ordinance permitting the city forester to condemn and remove diseased trees on private property at the owner's expense. The process of

identifying the diseased trees on private land by conventional ground survey is time consuming. The city officials and South Dakota Division of Forestry are hopeful that remote sensing techniques can significantly reduce the amount of time and expense needed to perform the inventory of private trees.

PROCEDURES

It was proposed to collect 1:6,000 scale color infrared aerial photography and thermal infrared data during early July and late August. However, eastern South Dakota experienced an unusually wet summer. Consequently, cloud cover restricted any data collection until late July. An attempt was made to collect data in late July however the airplane developed engine problems shortly after takeoff and was subsequently grounded for four weeks for repairs. Color infrared aerial photography was finally collected in early September. A camera malfunction severely overexposed approximately half of each frame of the film resulting in the film being of minimal use for an operational disease detection program. No thermal infrared was collected because of a scanner malfunction.

Despite the initial problems in obtaining data both the city of Watertown and the South Dakota Division of Forestry are still interested in pursuing the project. It was mutually decided to utilize the data which had been collected to develop and refine interpretation procedures to be used in an operational program.

RESULTS

A meeting was held with the Watertown city forester and a representative of the Division of Forestry to determine what information

and assistance was needed to utilize the existing data effectively. It was determined that in order to enable an interpreter to learn to identify tree specie it would be necessary to compare the film to the existing citywide public land tree inventory data. After making only a few comparisons on the day of the meeting it became easier to identify species. Species identification was more difficult in portions of the city where trees were more dense and had overlapping canopies. Species identification appeared to be much easier in areas where the trees were less dense. It is hopeful that the existing tree inventory will prove useful in solving any problems.

Another problem encountered is identifying actual number of trees when there are several trees located so close to each other that the tree canopies overlap. The problem was only evident in the older areas of the city where most of the trees are very large. In the newer areas of the city individual trees are easily identified. The use of the inventory data assisted in determining the number of trees and will be useful in developing interpretation procedures to help identify the actual number of trees within an overcrowded stand. The problem should not be significant once the interpreter develops the necessary producedures for separating overcrowded trees. Figure 1 illustrates the varying density of trees from older to newer residential areas.

Currently the film is being reviewed to determine which portions of the city have suitable photographic coverage. The areas are being delineated on a city base map. The city of Watertown is going to provide the corresponding inventory data to allow an interpreter to become fully trained to identify tree species and location.

Figure 1. Illustration of varying tree density from older to newer residential. Note the distinct difference in coloration of two trees circled, which is an indication of species.

ANTICIPATED WORK

Interpretation procedures for identifying individual trees in dense stands and species will be developed throughout the remainder of the winter season. Near the end of June another attempt will be made to collect color infrared photography and thermal infrared data. Once the data have been collected the pretrained interpreter will be able to quickly and accurately identify diseased elm trees. The information will be conveyed to ground crews so inspection and removal can begin immediately. Accurate records will be kept by the city of Watertown forester in order to evaluate the accuracy of the data and effectiveness of the project. The Division of Forestry will be closely evaluating the entire process to determine applicability for a statewide program. The thermal infrared data will be analyzed to determine any potential application for detecting stress conditions caused by Dutch elm disease.

A FEASIBILITY STUDY FOR MONITORING EFFECTIVE PRECIPITATION IN SOUTH DAKOTA USING TIROS-N

Improved estimates of soil moisture and rainfall distribution are important for agricultural and hydrological applications (yield forecasting, pest management, runoff modeling, flood forecasting, etc.). In drafting South Dakota's response to the National Climate Act, a Workshop of Climatic Data Users set establishment of a soil moisture information network as a top-priority for the state. The Workshop recognized that soil moisture budgeting will be an integral part of a soil moisture network.

Suitable soil moisture budget models have been developed (Heilman et al., 1978). However, a weak link in the models is uncertainty in estimates of effective precipitation (infiltration), a major input of the models.

Most problems related to soil moisture detection occur during the summer when precipitation is primarily from convective thunderstorms. An understanding of the spotty nature of convective rainfall is extremely important since the environment operates on rainfall through variations in slope, soil type, vegetation, climate, etc.

Many remote sensing investigations have addressed the topic of soil moisture (see summary by Heilman et al., 1978) ranging in sensors from visible through radar. Their results are principally site specific and only on bare and limited types of vegetated surfaces. Vegetation vigor and growth, thermal inertia, and evapotranspiration have been

identified as surface features which are related to reflective and thermal land surface measurements and are often related to soil moisture. An effort to evaluate factors of slopes, soils, vegetation, climate, and other influencing parameters is of prime importance but will take large and comprehensive investigations to determine the basic interactions and develop models to reduce the effects of these interactions. Multitemporal remote sensing has the advantage of repetitive observations over the same point of the land surface holding these interacting variables constant over short time periods, i.e. daily observations. Day-to-day changes in reflectance and/or emittance are normally minimal unless events such as rainfall occur. In addition, the interacting landscape variables are held relatively constant in time-sequential analyses of changing reflectance or emittance patterns.

Currently, the National Weather Service of NOAA uses rain gauge measurements of precipitation in the Palmer Drought Index (PDI) and Crop Moisture Index (CMI) to characterize regional soil moisture conditions (Palmer, 1968). However, it is difficult to interpret the generalized PDI and CMI for specific locales and specific applications, since neither index responds to growth and development of specific crops.

Heilman et al. (1977) estimated soil water depletions in a 150 cm profile for winter wheat in five Great Plains states using an evapotranspiration/soil moisture budget model and Landsat estimates

of leaf area index. They found that estimated depletion patterns compared favorably with CMI and, unlike CMI, could be interpreted in terms of yield. A weak link in this procedure is uncertainty in precipitation measurements and effective precipitation estimates because of the reliance on present rain gauge networks.

Researchers have found that the potential exists for using remote sensing of cloud formations to improve rain gauge network estimates of precipitation. Griffith et al. (1978) developed a procedure for operationally estimating 24-hour areal precipitation from weather satellites during hurricanes. Follansbee and Oliver (1975) developed an empirical method for estimating 24-hour rainfall in the tropics and subtropics using visible or infrared data from polar-orbiting satellites.

Scofield and Oliver (1977a) developed a procedure for estimating rainfall on a half-hourly or hourly basis using GOES data with the assumption that there is a primary relationship between rainfall intensity, cloud top temperature, and storm growth as determined from GOES imagery. Using that procedure, Scofield and Oliver (1977b) estimated rainfall for a convective thunderstorm over Chicago and found that the average half-hour estimated rainfall using GOES data was within 0.43 cm of observed values for an extremely heavy thunderstorm. The above procedures have demonstrated considerable skill in estimating precipitation in tropical and subtropical regions by evaluating cloud formation. The Scofield and

Oliver procedure has shown promise for estimating rainfall from heavy precipitation events at mid-latitudes. However, for modeling soil moisture, yield, runoff, etc., rainfall distribution patterns and estimates of effective precipitation are required.

Thompson (1976) found that Landsat spectral data showed promise for delineating precipitation patterns in a multistate wheat producing area. In addition, he found that Landsat data provided a more accurate estimate of drought affected areas than did CMI.

The potential exists for viewing the earth's surface before and after convective precipitation events using visible, near infrared, and thermal infrared wavelengths to evaluate distribution patterns and estimate effective precipitation for water budget modeling. Precipitation will affect the spectral response of the surface through three major mechanisms:

* thermal inertia of the soil
* evapotranspiration from the surface
* crop response ("green-up" of vegetation).

Because of the dynamic nature of growth and development of vegetation, and the variation in species, soils, microclimate, etc., in semi-arid areas, all three mechanisms must be evaluated.

* Thermal Inertia - If a bare soil surface layer is not saturated, rainfall will increase the thermal inertia (defined as $(\rho C\lambda)^{\frac{1}{2}}$ where ρ is density, C is heat capacity, λ is thermal conductivity of the surface layer). As a result, differences

between the surface temperature of bare soil near the maximum and the minimum of the diurnal temperature cycle (Δ T) will generally be less following rainfall. Idso et al. (1975) found that ΔT was related to soil moisture in the surface layer (0 to 5 cm) of soil. Idso et al. (1976) found that environmental variability, particularly air temperature effects, could be reduced using the diurnal air temperature difference as a normalizing factor. A quantity "apparent thermal inertia" defined as constant x (1.0 - albedo)/(day temperature-night temperature) has been developed for the Heat Capacity Mapping Mission (HCMM) to test the feasibility of inferring soil moisture from satellite observation. Price (1977) gives some theoretical justification for this formula. Gillespie and Kahle (1977) showed that apparent thermal inertia can be related to true thermal inertia.

Surface evaporation is a complicating factor because it reduces the net energy input and thus reduces the amplitude of the surface diurnal temperature cycle. Thus ΔT is an indicator of some combination of soil moisture and surface evaporation.

A further complicating factor is the effect of vegetation on ΔT. Moore et al. (1975) showed that thermal emittance, irrespective of vegetation, was significantly related to soil moisture, but that both reflective and thermal bands were required to separate vegetation and soil moisture effects. They also found significant moisture-related differences between thermal emittances of irrigated and non-irrigated areas.

* Evapotranspiration (ET) - Precipitation will influence the evaporation from the soil surface. Precipitation in sufficient amounts will also affect transpiration if soil moisture in the root zone is limiting. Increases in evapotranspiration will affect the temperature regimes by evaporative cooling of the soil surface and transpirational cooling of vegetation.

* Crop Response - Precipitation will produce "green-up" of brown (dormant) vegetation, particularly range vegetation during normally dry periods. It is not uncommon to have "green-up" of short grass range vegetation within 24 hours following rainfall of 0.6 cm (0.25 inches). The effect will be most pronounced for shallow-rooted vegetation and less for deep-rooted vegetation. "Green-up" will change the spectral response, transpiration, and the temperature regime of the vegetation.

Therefore, it appears that spectral information may be useful for evaluating rainfall distribution and estimating effective precipitation and soil moisture by viewing the spectral response of soils and vegetation before and after convective precipitation events. Techniques must be employed that evaluate thermal inertia, evapotranspiration, and crop response to rainfall. Evaluations of remote sensing of these three mechanisms are available in the literature, but for an operational system for monitoring rainfall distribution, and in-depth investigation must be conducted.

The objective of this investigation is to:

* Evaluate the feasibility of using weather satellite data (TIROS-N) to monitor effective precipitation for use in a soil moisture network in South Dakota.

Application of using changes in the land surface as an indicator of rainfall should provide better estimates of effective precipitation (portion of rainfall that infiltrates). This approach does not rely on models that require extensive parameters for estimating runoff and infiltration. At a minimum the technique should provide better spatial estimates of convective precipitation than current rain gauge networks.

Weather satellite data, especially TIROS-N, have the coverage frequency as well as spatial and spectral properties to be an extremely valuable tool. Table 1 summarizes the characteristics of TIROS-N. This increased spatial resolution is especially valuable in assessing the spotty rainfall from convective precipitation which is the major source of precipitation for many regions during summer months. Because factors such as soil, topography, vegetation cover, and climatological and phenological time affect rainfall moisture retention, reflectance, and emittance and their variabilities, an analysis must be undertaken to determine under what specific conditions the procedures are applicable. Additionally, the time dependency of significant influence on reflectance and emittance caused by rainfall may provide information on the quantity of rainfall and on the effective (retained) precipitation.

Table 1. Characteristics of TIROS-N System.

Satellite	Sensor	Spectral Regions (μm)	Frequency of Coverage	Spatial Resolution	Thermal neΔT
TIROS-N	AVHRR	0.55 to 0.90	Twice	1.1 km	
		0.725 to 1.10	daily	1.1 km	
		3.55 to 3.93		1.1 km	
		10.5 to 11.5		1.1 km	0.2

STATUS OF INVESTIGATION

Daily rainfall estimates for July and August, 1979, were provided by the South Dakota Department of Water and Natural Resources (DWNR). DWNR operates a network of approximately 1500 rain gauges (Fig. 1).

A network of 81 soil sampling sites was established (Fig. 2) with sites selected to represent the major soil associations in the state. Land use categories were restricted to pasture and small grains. Soil samples for determining water content were collected at ten day intervals for each site during July and August, 1979. Percent cover was also estimated at each site.

TIROS-N imagery have been received and are being compared to rainfall and soil moisture estimates to locate apparent reflectance/emittance anomalies associated with moisture distribution patterns. There are no results of this analysis to report at this time.

ANTICIPATED RESULTS

The results of the investigation will be an evaluation of the utility of using TIROS-N data to evaluate effective precipitation. If positive results are found, additional analyses will be conducted in future investigations to quantify effective precipitation for use as an input into soil moisture budget models.

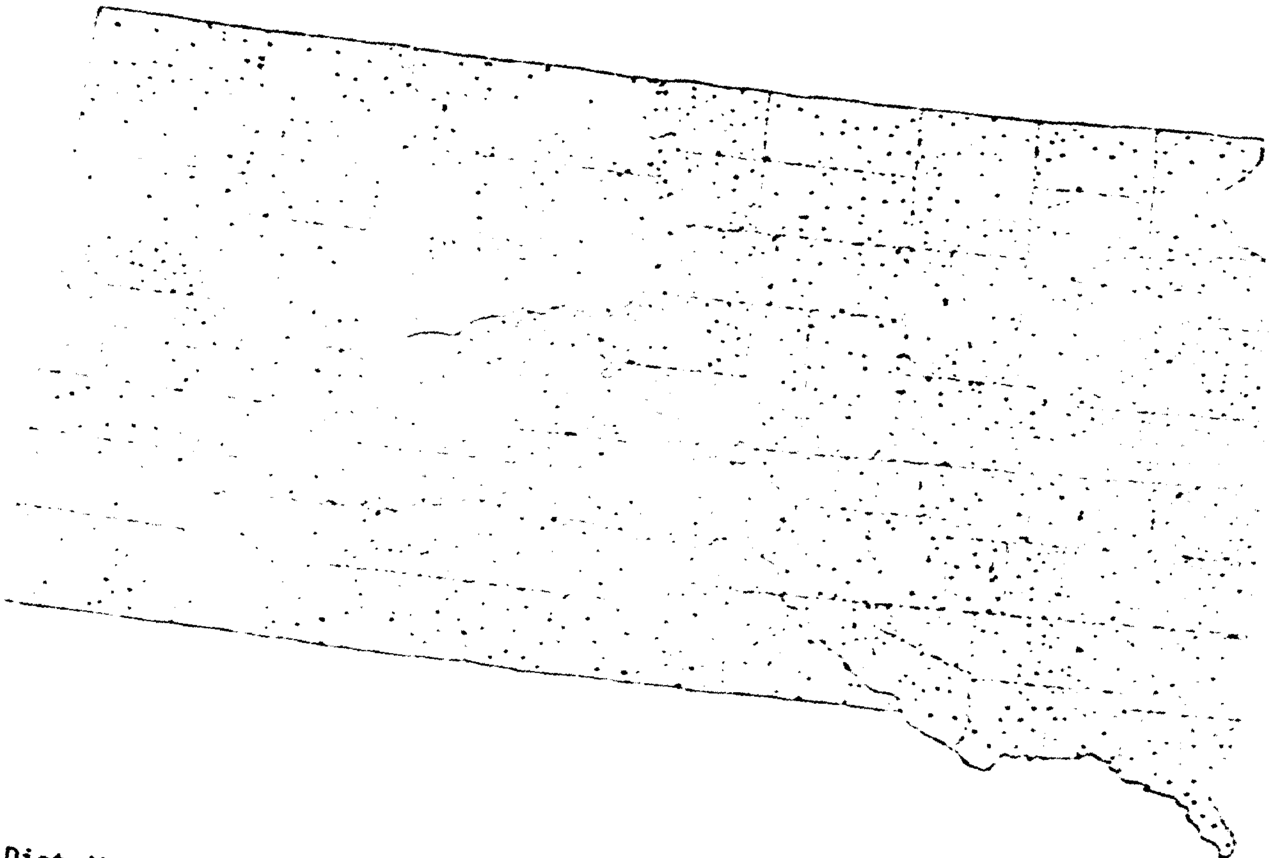

Fig. 1. Distribution of 1500 rain gauges in South Dakota. The network is operated by the South Dakota Department of Water and Natural Resources (DWNR).

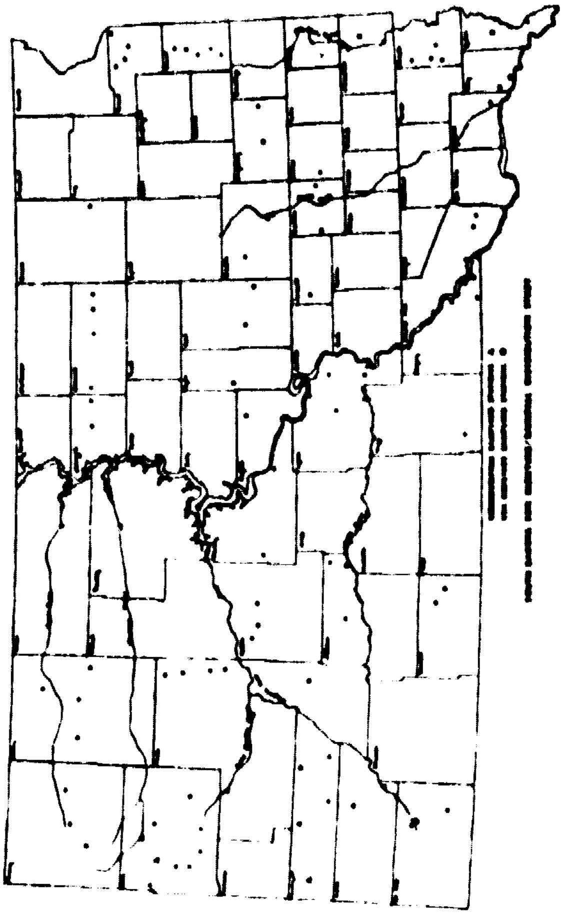

Fig. 2. Distribution of soil sampling sites established for the TIROS-N investigation.

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SURVEY AND ANALYSIS OF POTENTIAL POLLUTION FROM OPEN AND ABANDONED SOLID WASTE DUMP SITES USING REMOTE SENSING TECHNIQUES

INTRODUCTION

There are numerous unauthorized open and abandoned solid waste dumps still in existence. The majority of these dumps have been and are still utilized without concern for sound environmental practices. Potential health and environment hazards that are created by open and abandoned dump sites may include pollution of ground and surface waters from leachates and runoff; the breeding of germs, insects, and disease carrying rodents; potential fire hazard; generation of methane gas; and the creation of an unsightly nuisance.

Currently local, state and federal government agencies are cooperatively involved in solid waste management in Spink County and the surrounding area. The Fourth Planning and Development District is presently developing a regional solid waste management plan for its ten-county area of which Spink is one county. The South Dakota Department of Environmental Protection is presently developing a state-wide solid waste management plan. This plan must identify the responsibilities and authorities for implementation of the State Plan, prohibit establishment of new open dumps, and provide for the closing and upgrading of all existing open dumps, among other items. The U.S. Environmental Protection Agency (USEPA) is required by law to inventory all disposal facilities or sites in the United States which

are open dumps, and those that do not meet the requirements of a sanitary landfill will be placed on a compliance schedule for closure or upgrading.

The problem is to determine where and how many sites exist and potential pollution problems. Many of the sites are near small towns but many more are in rural areas where generally a small group of people dump waste. The conventional way to find the sites would be a windshield survey of the area. Unfortunately this method is very costly, extremely time consuming and ineffective in locating sites not near main roads. Remote sensing techniques, which are generally cost effective for large area reconnaissance, were used to locate and map open and abandoned dump sites in Spink County.

STUDY AREA

Spink County encompasses approximately 968,000 acres. There are 11 communities and, according to the 1970 Census, a population of 10,595. The major land use in this area is agricultural. The James River and the James River Basin, with numerous meandering streams, are partially located within Spink County.

PROCEDURES

Existing and newly acquired high altitude color infrared photography was interpreted to identify dump sites in Spink County. Two sources of NASA high altitude photography were used. Initial

interpretation was performed using June 1975 1:60,000 scale photography. The 1975 photography provided about 75% coverage of the county.

Color infrared 1:120,000 scale photography for the entire county was acquired in June 1979 in conjunction with other projects. The quality of the data was considerably less than that of the 1975 data. Segments of many frames were overexposed and some clouds and cloud shadows were present. The photography was also interpreted for dump sites.

Ground truth information for known existing open dumps was provided by the Fourth Planning and Development District. The information was the location of the dump sites near each of the towns within the county. The ground truth information helped train an interpreter to recognize potential dump sites.

The location of a possible dump site was determined by using two key indicators. They were the presence of a mottled texture and tone, which was distinct from the usually homogeneous texture and tone of the surrounding area, and the presence of a road or trail used by vehicles to deliver the waste. Both dates of imagery were interpreted using a 7x magnifying eyepiece (see Figures 1 and 2). A combination of 146 probable dump sites were interpreted from the 1975 and 1979 imagery.

The accuracy of the interpretation was determined by field checking. Field checking was performed by flying at low altitude in a light plane from site to site. The light plane method was chosen because of the difficulty in reaching sites not near roads and because considerable time could be saved in comparison to driving to each site. It took only three hours to verify 72 sites.

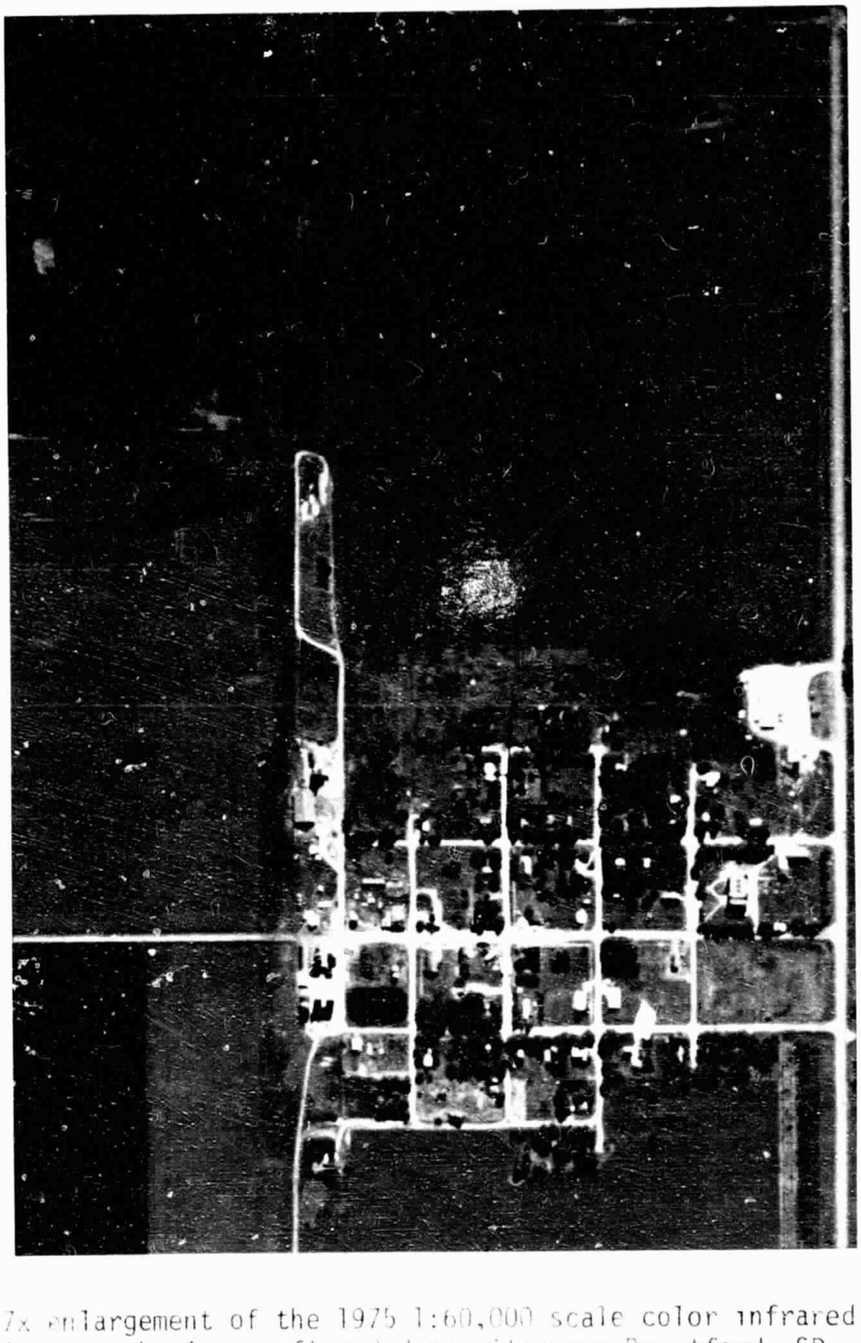

Figure 1. 7x enlargement of the 1975 1:60,000 scale color infrared imagery showing confirmed dump site near Brentford, SD.

Figure 2. 7x enlargement of the 197[illegible] 1:60,000 scale color infrared imagery showing confirmed dump site in eastern Spink County.

Of the 72 sites checked, 33 were actual garbage dump sites, 20 were junk piles composed of lumber, automobiles, and machinery, and 19 were not dump sites of any kind. Careful observation of the ground was necessary for navigation from site to site. Only one dump site which had not been interpreted from the imagery was found during the field checking. This indicates that the interpretation procedure resulted in detecting almost every probable dump site.

Based on the interpreted dump sites, which were field checked, the level of accuracy for detecting probable garbage dump sites is 46%. If junk sites which closely resemble garbage dump sites were included the accuracy increases to 75%.

A comparison of the accuracy results for dump sites interpreted from both scales of imagery was made to determine if one would be more advantageous. Of the 33 confirmed dump sites 19 were interpreted from the 1:60,000 scale imagery and 22 from the 1:120,000 scale photography. Consideration must be given to the fact that the 1:60,000 scale photography provided only 75% coverage of the county, the quality of the 1:120,000 scale imagery was quite poor and some sites could have been created after 1975. These three considerations make it difficult to evaluate which scale is better.

Other resource information concerning each site's pollution potential was also considered. The basic land use surrounding each dump site was interpreted from the 1979 high altitude photography. The land use was grouped into four basic categories: cropland, pasture, riparian, and farmstead. The distance to surface water was

calculated from USGS 7 1/2 minute topographic maps. The maps were used because the poor quality of the 1979 film made it difficult to accurately determine the drainage. The surface water bodies were either a stream, lake or marsh. No information concerning location of shallow groundwater or any other geologic information was available.

The dump site inventory was put in tabular form. The tabular information included a site number, the location based on a township and range system, the name of the USGS 7 1/2 minute quadrangle map in which the site is located, whether or not it was verified, the surrounding land use type, proximity to surface water, type of surface water and date of imagery from which the site was delineated (see Table 1). The sites were also annotated on the appropriate USGS 7 1/2 minute topographic map to facilitate finding the sites while in the field.

SUMMARY AND CONCLUSIONS

Interpretation of two dates and scales of imagery delineated 146 potential open or abandoned dump sites. The interpreted and ancillary data were put into tabular form for easier use. State government agencies will use the data to assist in development of the Spink County solid waste management plan and as input into the implementation of the State Plan to prohibit establishment of new dump sites and provide for closing of all existing open dumps. The study provides an economically feasible method to the US EPA who has the responsibility to inventory all facilities or sites in the United States.

Table 1. SPINK COUNTY OPEN AND ABANDONED DUMP SITES

Site #	Location	Quadrangle	Type	Surrounding Land Use	Surface Water Proximity to	Type	Date of Imagery
1	SW Corner, SW¼, Section 9, T 120 N, R. 65 W.	Chelsea	Unknown	Cropland	3000 ft.	Stream	1975
2	SW Corner, SE¼, Section 21, T 118 N, R 65 W	Northville SW	Garbage	Cropland	2800 ft.	Stream	1979
3	NE Corner, NE¼, Section 8, T 117 N, R 65 W	Zell	Unknown	Cropland	800 ft.	Pond	1975
4	NW Corner, SW¼, Section 5, T 116 N, R 65 W	Zell	Unknown	Abandoned Farm	<500 ft.	Stream	1979
5	SE Corner, SE¼ Section 32, T 116 N, R 65 W	Redfield SW	Unknown	Pasture	750 ft.	Stream	1975
6	SE Corner, SE¼ Section 6, T 115 N, R. 65 W	Redfield SW	Unknown	Pasture	750 ft.	Lake	1979
7	SE Corner, NE¼, Section 32, T 114 N, R 64 W	Tulare	Unknown	Pasture	1200 ft.	Stream	1979
8	NE Corner, NE¼ Section 29, T 114 N, R 64 W	Tulare	Unknown	Pasture	3000 ft.	Stream	1975
9	SE Corner, NE¼, Section 8, T 114 N, R 64 W	Tulare	Unknown	Pasture	500 ft.	Pond	1979
10	NW Corner, SE¼ Section 28, T 115 N, 64 W	Tulare	City Dump	Cropland	>4000 ft.	Pond	1979
11	[illegible] Corner, SW¼ Section 19, T 115 N, R 64 W	Redfield S	Unknown	Pasture	800 ft.	Stream	1979

INFLUENCE OF SOIL REFLECTANCE ON LANDSAT SIGNATURES OF CROPS

Introduction

Accurate areal forecasts of world-wide crops are important in governmental policy and in crop marketing and planting strategies. Fluctuations in the production of various commodities around the world have serious economic and humanitarian implications.

Numerous investigations have shown the efficacy of remote sensing technology in estimating crop acreages (Richardsen et al., 1977; Hanuschak et al., 1979; Paarlberg et al., 1978). The need for improved crop forecasts and the role of AgRISTARS, a USDA five-year remote sensing research program, have been addressed by Powers et al. (1979). The AgRISTARS program has assigned a high priority to commodity production forecasts and any changes which affect production.

Accurate crop identification from Landsat data is a necessary prerequisite to real-time large-scale production estimates. Improvement of Landsat data for crop area estimates has been shown through digital transformation (Kauth and Thomas, 1976). However, alternative methods also need investigation. Stratification of land regions by soil parameters has, in some cases, shown promise for improving crop area estimates from Landsat data (Dalsted et al., 1979), while in another study the results have been less than

encouraging (Myers et al., 1979). Another supporting argument for stratification of Landsat data is the potential relationship between a relatively uniform strata and the yield potential of the land therein.

Economics, Statistics, and Cooperatives Service (ESCS) of the USDA and RSI conducted a research investigation in 1979 utilizing soil-based criteria as a means of stratifying a county to improve Landsat classification of crops (Myers et al., 1979). The approach of this study is based on stratification derived from photo-interpretation of multidate Landsat imagery (one scene) rather than using only soil-based parameters, per se. The primary objective of the study is to investigate a means of improving crop recognition from classification of Landsat data by stratifying the Landsat scene into regions of relative homogeneity. A concurrent part of this study will provide, for Spink County, an estimate of the acreage of sunflowers, a crop of rapidly increasing acreage and economic importance in South Dakota.

Study Area

The region of investigation is shown in Fig. 1. Physiographic diversities and agricultural activities of this region have been detailed (Westin and Malo, 1978). Corn, wheat, oats, and barley are the major crops in this region. Sunflowers, however, are rapidly becoming a major crop in certain parts of the study area.

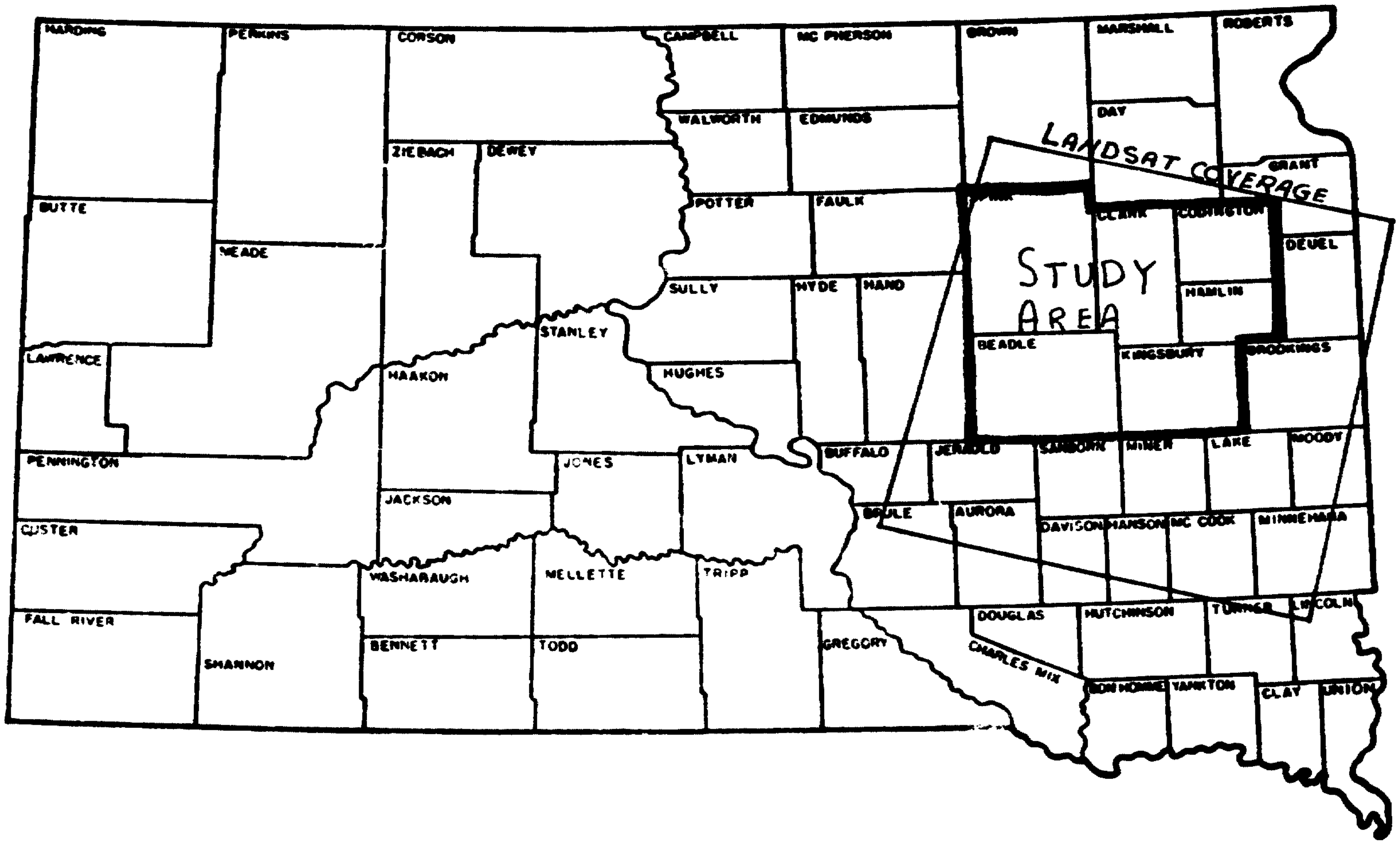

Fig. 1. Location of study area in crop-soil spectral study. Boundaries of the Landsat scene and the counties included in the study are outlined.

This region is characterized by hot summers and cold winters. Precipitation occurs predominantly in the spring and early summer months.

Materials and Methods

The study area was divided into 10 strata by photo-interpretation of 1:250,000 1978 Landsat prints (May, July, September scenes). Location of representative ground samples within each stratum was determined by ESCS techniques (Von Steen and Wigton, 1976). The samples or segments were generally one-quarter section in area and totaled 255 for the entire region. The number of segments per stratum was weighted according to the area of the respective stratum.

Ground investigation was accomplished by an on-site description of the land use at each of the segments. Aerial photography (1:15,840 scale) was used as a base for outlining field boundaries, notating crops and crop phenology at each segment. The aerial photography used in the field investigation were varied in year of collection, the majority being in the 1975 to 1979 bracket.

Two Landsat Computer Compatible Tapes (CCT's) were obtained by the ESCS for use in this study. The dates of coverage were 20 July and 25 August 1979. Data extraction procedures (Cook, 1977) have been initiated by the ESCS. RSI personnel have assisted the ESCS in error checking, data movement, and the other aspects of the data extraction. The extracted data have been compartmentalized by stratum, segment, and field with the appropriate crop and phenology information.

Clustering analysis will take place next. Analysis of the various statistical aspects of the data will be accomplished using established ESCS procedures. The null hypothesis of the study is that the stratification of the Landsat does not significantly improve crop classification accuracies. Probable analysis include multitemporal analysis and scene classification.

Report of Project Status

No results have been generated at this juncture. However, progress leading toward the final analysis is ahead of schedule. The exact status of this study is listed in the Methods section.

While this study may be considered a "follow-up" to the 1979 project (Myers et al., 1979), the photo-interpretive approach for stratification of Landsat space is less arbitrary than a strictly soil-based stratification since the types and expressions of soil properties vary greatly from region to region. While photo-interpretation, as used in the study, is not an exact means of partitioning the region, the factors considered in photo-interpretation are far less numerous than indigenous soil properties which vary on continuous basis across this area. It appears that stratification procedures, as used in this project, are more easily determined than a soil-based stratification. As a consequence, a large scale project would in theory contain a sizeable set of soil properties upon which stratification would arbitrarily be based on a subset of these soil properties, determined according to the investigators' view of "importance" of the soil properties.

The use of crop phenology, or stage of maturity, will provide a valuable means of reducing the variance associated with different crop planting dates. The stage of maturity varies considerable from south to north.

An adjunct to the original study was added because of interest in the rapid expansion of sunflower area in 1979. Spink County data will be used by the ESCS to further refine current areal estimates of sunflowers.

Utilization of successfully derived results is anticipated by ESCS, Crop Reporting Districts, Extension Service, Livestock Reporting Service, and others that have a need for a procedure of improving crop area estimates. Sunflower results generated from this project will have a direct use in 1979 crop estimates by the Crop Reporting District; this is especially important in light of increased emphasis of sunflower production.

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C-2

APPLICATION OF REMOTE SENSING IN THE NATIONAL MODEL IMPLEMENTATION PROGRAM, LAKE HERMAN WATERSHED

INTRODUCTION

In 1978 Lake Herman watershed near Madison, South Dakota was selected as one of seven water resources systems in the United States to participate in the national Model Implementation Program (MIP). MIP is a pilot cooperative program by USDA and USEPA. The program is designed to test and evaluate various water resources quality improvement methods.

Several South Dakota groups are cooperating in the Lake Herman MIP program. They include: Lake Herman Development Association, First Planning and Development District, East Dakota Conservancy District, South Dakota Department of Natural Resource Development, South Dakota State University Extension Service, United States Department of Agriculture (USDA) Agricultural Stabilization and Conservation Service, Remote Sensing Institute (RSI), and the USDA Soil Conservation Service (SCS). SCS has been designated the "lead" agency in the Lake Herman MIP program.

It was determined by consultation with the numerous agencies involved with the MIP program that a means of monitoring land use and hydrologic changes was a definite requirement. The SCS suggested that remote sensing would provide a valuable input to this monitoring and evaluation process. In 1978, NASA and SCS funded data collection

and analysis and provided technical expertise for establishment of an inventory of the baseline condition of the watershed. Baseline land cover data for the 1978 growing season and detailed soil survey data were coded into RSI's Area REsource Analysis System (AREAS), a computerized cellular information system (Wehde, 1979). The data were analyzed to produce tabular and map information concerning location, quantity and severity of soil erosion (Myers, et al. 1979). This information is being utilized in management decisions for the watershed. It was necessary to acquire up-to-date information for the 1979 growing season in order to effectively monitor change occurring within the watershed through the duration of MIP. The information has been included into AREAS to improve the monitoring and evaluation process.

PROCEDURES

1979 Land Cover

Initially it was intended to utilize NASA high altitude photography acquired during the 1979 growing season for interpreting the land cover. Unfortunately weather conditions prohibited data collection during the time period requested. Consequently, 70 mm 1:61,000 scale color and color infrared photography was acquired on 29 August using the RSI aircraft.

Ground truth data for the watershed were collected prior to the interpretation of the photography. The ground truth data were obtained by recording the land cover type that occurred in each quadrant at most

road intersections within the watershed. The information was used to train the interpreters and verify interpretation results.

Twelve land cover categories identical to those used for the 1978 data were interpreted. The 1979 land cover data were computerized using a method similar to the 1978 process (Myers et al. 1979). The land cover data were computerized one square mile at a time. The data for each square mile was enlarged to approximately 1:11,000 using an International Imaging Systems (I^2S) color additive viewer.* The enlarged data were overlaid with a 32 x 32 cell grid. Each cell represented .25 hectares (.625 acres). A change point coding procedure was used whereby only grid points in which boundaries are coded. Each cell was classified, based on category dominance within the cell.

The digitized data for each section was machine plotted on a transparent material. The section data was overlaid onto the photography to ensure all category boundaries were digitized correctly.

RESULTS

Sediment Control Structure Site Planning

One of the major MIP activities of SCS is the planning and construction of sediment control structures. At least three major structures and several minor structures will be constructed. During the summer of 1979 SCS was involved in planning a major sediment control structure in the drainage entering the southern tip of Lake Herman.

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*Inclusion in this report of registered tradenames or trademarks does not constitute an endorsement by the author or the Remote Sensing Institute.

The SCS utilized specific map and tabular information derived from AREAS throughout the planning and design of the sediment control structure. One of the major uses of the information was to determine the necessary size of the structure. The SCS utilized land cover, land treated, land in need of treatment and soil capability class information to estimate potential precipitation runoff and soil erosion.

Another use of the information was to determine potential sites. Sites were determined from a slope map of the watershed. The map delineated areas of steep slopes suitable for construction sites. The final site was selected from field surveys.

ANTICIPATED WORK

The 1979 land cover data will have two immediate uses. First, comparison of the 1978 and 1979 land cover will be made to determine crop rotation practices. This information is needed by SCS to locate land areas which may be susceptible to severe soil erosion and productivity problems due to poor management.

Secondly, the 1979 land cover data will be used in an expanded sediment control structure planning effort. At least two more major sediment control structures are planned. At the request of SCS, information is being provided for planning the two sites.

In addition, SCS is cooperating in the development of a model to estimate sediment delivery. The model will weigh each cell based on land cover, land treatment, capability class and distance to

drainage. This data is already in the information system. The output of this model will be used to evaluate the effectiveness of the control structures for trapping sediment before it reaches the lake. Also, the model will be used to estimate changes in sediment yield with varying land management practices.

SUMMARY AND CONCLUSION

The Lake Herman MIP is in the second year. During the first year the baseline condition of the watershed was determined using remote sensing and soils information. Emphasis has changed from the entire watershed to individual studies of the areas delivering sediment to the lake. Information developed by RSI was used to plan and design sediment control structures. A model is being developed to estimate sediment delivery to the lake. The model will be used extensively by SCS for planning and evaluating the structures.

The information which has been produced has assisted SCS in planning throughout the watershed. The remote sensing information is being used extensively to monitor and evaluate the land and water quality improvement practices implemented in the project.

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SIX-MILE CREEK INVESTIGATION FOLLOW-ON

INTRODUCTION

An investigation was initiated in 1978 to evaluate the geohydrology and the environment of Six-Mile Creek Watershed near Brookings, South Dakota to evaluate the impact of a proposed dam and reservoir site (Myers, et al., 1979). Thermal and color IR data were used by SCS and RSI personnel to evaluate the ground water situation, complete a land use inventory, and characterize erosion potential for preparation of an environmental impact statement. Specific objects were to:

1) Select sites for drilling observation wells
2) Evaluate water-table depths
3) Evaluate soil moisture
4) Evaluate erosion potential

These objectives were met in FY 79. An extension of the Six-Mile Creek Investigation was requested so that results of the drilling program (objective 1) could be fully documented. Refer to the '1979 Annual Report SDSU-RSI-79-14 for a complete discussion of the investigation.

RESULTS

A ground water investigation of the proposed dam and recreation site on Six-Mile Creek Watershed (Fig. 1) is required to evaluate

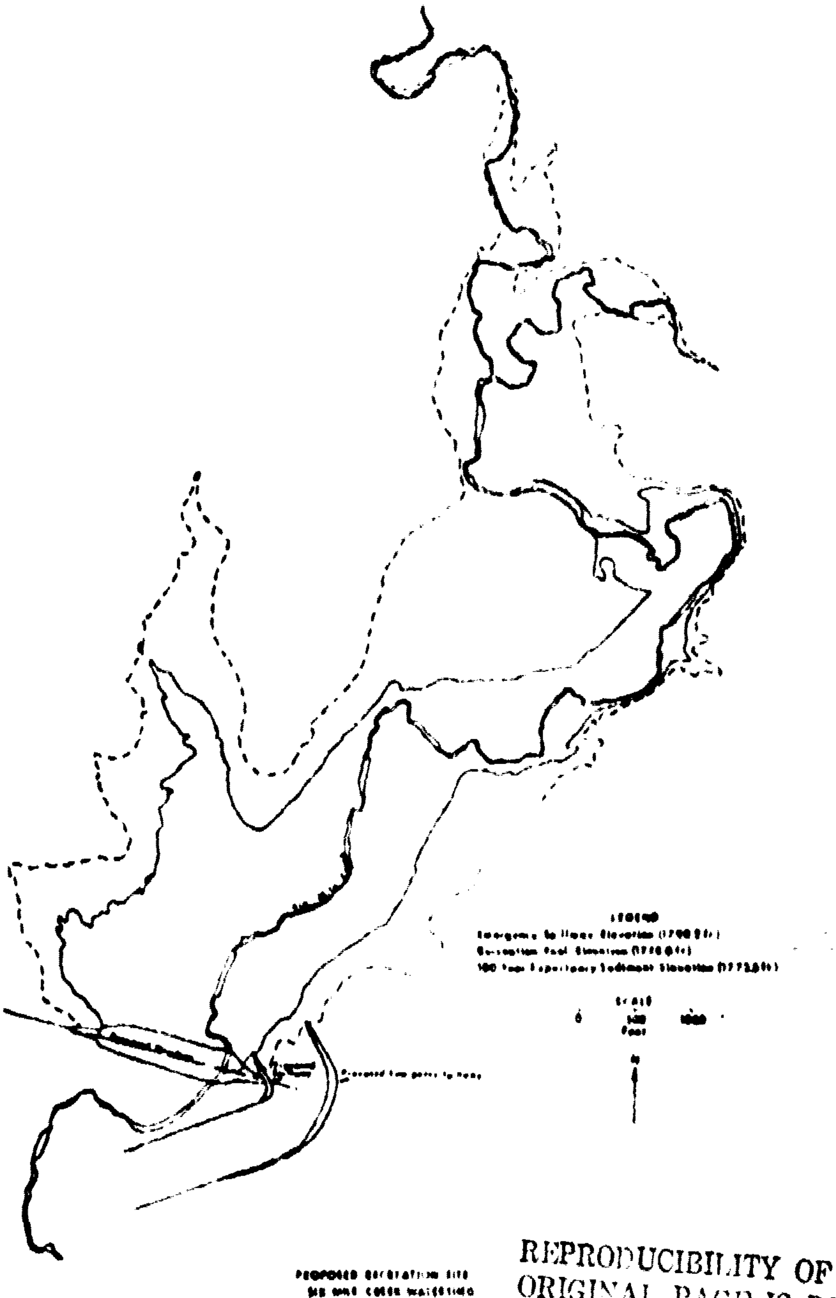


Fig. 1. Description of proposed recreation site on Six-Mile Creek Watershed.

potential seepage losses. The investigation consists of drilling and logging of observation wells to evaluate the vertical extent and layering of permeable aquifer material. Wells are installed so that ground water heads can be measured independently in each aquifer at multiple lateral locations. Relative and actual permeability and boundaries of permeable material must be known to design seepage cutoff and drainage control under the structure.

The geohydrologic investigation of the site was initiated in 1978 with the drilling of 11 observation wells along the proposed structure site and near the northern end of the pool area. Potential sites for drilling remaining wells were selected on the basis of the remote sensing imagery acquired in early September, 1978 (Myers et al., 1979). Thermal imagery of the recreation site revealed a broad cool pattern surrounding Six-Mile Creek (Fig. 2). The shape and location of the apparent thermal anomaly were typical of thermal patterns produced by shallow aquifers.

Test holes 805, 806, and 807 (Fig. 2), later renumbered 801, 802, and 803, respectively by SCS, were drilled in August 1979. Results of the drilling are summarized in Table 1 and Fig. 3-5. Drilling verified the presence of permeable alluvium at all three locations. Depth to water ranged from 1 to 5 feet below the soil surface. Observation wells and piezometers were installed at the three locations to monitor ground water fluctuations and head pressure.

Fig. 2. Daytime thermal image of proposed dam and recreation site on Six-Mile Creek Watershed. An apparent anomaly is delineated by dashed lines. Numbers are potential drilling sites. Approximate scale 1:16,000; dark is cool.

Table 1. Log of test boring for Six-Mile Creek.

LOG OF TEST BORING

JOB NO 620-1446 VERTICAL SCALE 1" = 5' BORING NO 801

PROJECT OBSERVATION WELL INSTALLATION - PROPOSED RECREATION AREA - WHITE, SOUTH DAKOTA

DEPTH IN FEET	DESCRIPTION OF MATERIAL (SURFACE ELEVATION ____)	GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	LABORATORY TESTS W	D	LL PL	Qu
2	SILTY CLAY, dark gray (CL)	TOPSOIL			1	FA				
6	SANDY CLAY, trace of gravel, dark gray (CL)	TILL		▽	2	FA				
9½	SANDY CLAY with gravel, dark gray, rather stiff, laminations of sand at 7'-8½' (CL)				3	SS				
13	SILTY SAND, dark gray, medium dense, laminations of medium grained sand at 11½'-13' (SM)	MIXED ALLUVIUM	11		4	SS				
	LEAN CLAY, a little gravel, dark gray, stiff, laminations of fine grained waterbearing sand (CL)	TILL	18		[illegible]	SS				
					6*	WS*				
					7*	WS*				
					8*	WS*				
					9*	WS*				
37					10	WS*				
40	LEAN CLAY, a little gravel, brownish gray, very stiff, laminations of fine grained sand (CL)									
	CONTINUED ON NEXT PAGE									

*No Sample Retained
**Washed Sample

SOIL EXPLORATION

LOG OF TEST BORING

JOB NO 620-1446 VERTICAL SCALE 1" = 5' BORING NO 801 (CONT.)

PROJECT OBSERVATION WELL INSTALLATION - PROPOSED RECREATION AREA - WHITE SOUTH DAKOTA

DEPTH IN FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	LABORATORY TESTS W	D	LL PL	Qu
40	SAME AS PREVIOUS PAGE	TILL	31		11	SS				
					12	WS*				
46	SILTY SAND, gray, very stiff (SM)	MIXED ALLUVIUM								
51	END OF BORING		41		13	SS				

* No Sample Retained
** Washed Sample

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE IN DEPTH	BAILED DEPTHS	WATER LEVEL
8-9	3:05	51'	None		to	5'
					to	
					to	
					to	

START 8-5-79 COMPLETE 8-5-79

METHOD 4C 0-7' @ 2:33

D.M. 7'-49½'

CREW CHIEF HANSON

LOG OF TEST BORING

JOB NO 620-1446 VERTICAL SCALE 1" = 5' BORING NO 802 A & B

PROJECT OBSERVATION WELL INSTALLATION - PROPOSED RECREATION AREA - WHITE, SOUTH DAKOTA

SURFACE ELEVATION

DEPTH IN FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	W	D	LL/PL	Qu
1	SILTY CLAY, black (CL)	TOPSOIL			1	FA				
	SANDY CLAY, a little gravel (CL)	TILL			2	FA				
3½	SAND, coarse and medium grained, some cobbles, brown, laminations of SANDY CLAY (SP)	COARSE ALLUVIUM			3*	WS*				
					4	WS*				
8½	SANDY CLAY, some gravel, red and brown mottled, stiff, lenses of waterbearing sand, gravel, and cobbles (CL)	TILL	16		5	SS				
					6*	WS*				
					7*	WS*				
14½	SANDY CLAY, a little gravel, dark gray, stiff, laminations of water-bearing sand at 31', cobbles at 14½'-17½' (CL)				8	..S*				
					9	WS*				
					10	SS				
31	***SEE NOTE #1		30		11	SS				
32	LEAN CLAY, a little gravel, brownish gray, stiff (CL)		30		12	SS				
36½	END OF BORING *No Sample Retained **Washed Sample ***NOTE #1 - SILT, light gray, laminations of waterbearing sand (ML)									

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE IN DEPTH	BAILED DEPTHS	WATER LEVEL
8-9	3:03	36½'	None	-	to	1'
					to	
					to	
					to	

START 8-6-79 COMPLETE 8-7-79

METHOD 4C 0 7' @ 12:45

D.M. 7'-35'

CREW CHIEF HANSON

LOG OF TEST BORING

JOB NO 620-1446 VERTICAL SCALE 1" = 5' BORING NO 803

PROJECT OBSERVATION WELL INSTALLATION - PROPOSED RECREATION AREA - WHITE, SOUTH DAKOTA

DEPTH IN FEET	DESCRIPTION OF MATERIAL (SURFACE ELEVATION)	GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	W	D	LL/PL	Qu
	SILTY CLAY, dark brown (CL)	TOPSOIL			1	FA				
2½	*** SEE NOTE #1	TILL		▽	2	FA				
3½	SANDY CLAY, trace of gravel, brown, samll cobbles and layers of medium and coarse grained sand at 6'-8' (CL)				3*	WS**				
8	SANDY CLAY, trace of gravel, brown, very stiff, cobles at 9½' and 11½' (CL)		52		4	SS				
12½	LEAN CLAY, trace of gravel, dark gray, stiff to very stiff, cobbles at 41.2' (CL)				5*	WS**				
			19		6	WS*				
	***NOTE #1 - SANDY CLAY, trace of gravel, grayish brown, cobbles at 3' (CL)				7*	WS*				
					8	WS*				
					9*	WS*				
35	CONTINUED ON NEXT PAGE									

*No Sample Retained
**Washed Sample

LOG OF TEST BORING

JOB NO 620-1446 VERTICAL SCALE 1" = 5' BORING NO 803(CONT.)

PROJECT OBSERVATION WELL INSTALLATION - PROPOSED RECREATION AREA - WHITE, SOUTH DAKOTA

DEPTH IN FEET	DESCRIPTION OF MATERIAL (SURFACE ELEVATION)	GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	W	D	LL/PL	Qu
35	SAME AS PREVIOUS PAGE	TILL								
			43/.7		10	SS				
41.2	OBSTRUCTION									

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE IN DEPTH	BAILED DEPTHS	WATER LEVEL
8-9	3:00	41.2'	None	-	to	3½'
					to	
					to	
					to	

START 8-7-79 COMPLETE 8-7-79

METHOD 4C 0-6' @

D.M. 6'-40'

CREW CHIEF HANSON

soil exploration company

SE-2 (77-8)

GENERAL NOTES

DRILLING & SAMPLING SYMBOLS

SYMBOL	DEFINITION
C.S.	Continuous Sampling
P.D.	2-3/8" Pipe Drill
C.O.	Cleanout Tube
3¼ HSA	3¼" I.D. Hollow Stem Auger
4 FA	4" Diameter Flight Auger
6 FA	6" Diameter Flight Auger
2½ C	2½" Casing
4C	4" Casing
D.M.	Drilling Mud
J. W.	Jet Water
H. A.	Hand Auger
NXC	Size NX Casing
BXC	Size BX Casing
AXC	Size AX Casing
SS	2" O.D. Split Spoon Sample
2T	2" Thin Wall Tube Sample
3T	3" Thin Wall Tube Sample

LABORATORY TEST SYMBOLS

SYMBOL	DEFINITION
W	Moisture content - percent of dry weight
D	Dry density-pounds per cubic foot
LL, PL	Liquid and plastic limits determined in accordance with ASTM D 423 and D 424
Qu	Unconfined compressive strength-pounds per square foot in accordance with ASTM D2166-66

Additional insertions in Qu column

Pq	Penetrometer reading-tons/square foot
Ts	Torvane reading-tons/square foot
G	Specific gravity - ASTM D 854-58
SL	Shrinkage limit - ASTM D 427-61
pH	Hydrogen ion content-meter method
O	Organic content-combustion method
M.A.*	Grain size analysis
C*	One dimensional consolidation
Qc*	Triaxial compression

*See attached data sheet and/or graph

WATER LEVEL

SYMBOL – ▼

Water levels shown on the boring logs are the levels measured in the borings at the time and under the conditions indicated. In sand, the indicated levels can be considered reliable ground water levels. In clay soil, it is not possible to determine the ground water level within the normal scope of a test boring investigation, except where lenses or layers of more pervious waterbearing soil are present and then a long period of time may be necessary to reach equilibrium. Therefore, the position of the water level symbol for cohesive or mixed texture soils may not indicate the true level of the ground water table. The available water level information is given at the bottom of the log sheet.

DESCRIPTIVE TERMINOLOGY

DENSITY

TERM	"N" VALUE
Very loose	0-4
Loose	5-8
Medium Dense	9-15
Dense	16-30
Very Dense	Over 30

CONSISTENCY

TERM	"N" VALUE
Soft	0-4
Medium	5-8
Rather Stiff	9-15
Stiff	16-30
Very Stiff	Over 30

Standard "N" Penetration: Blows per foot of a 140 pound hammer falling 30 inches on a 2 inch OD split spoon.

RELATIVE PROPORTIONS

TERM	RANGE
Trace	0-5%
A Little	5-15%
Some	15-30%
With	30-50%

PARTICLE SIZES

Boulders	Over 3"
Gravel	
Coarse	¾"-3"
Fine	#4-¾"
Sand	
Coarse	#4-#10
Medium	#10-#40
Fine	#40-#200
Silt and Clay	Determined by plasticity Characteristics

Note: Sieve sizes shown are U.S. Standard

SE-4(70A)

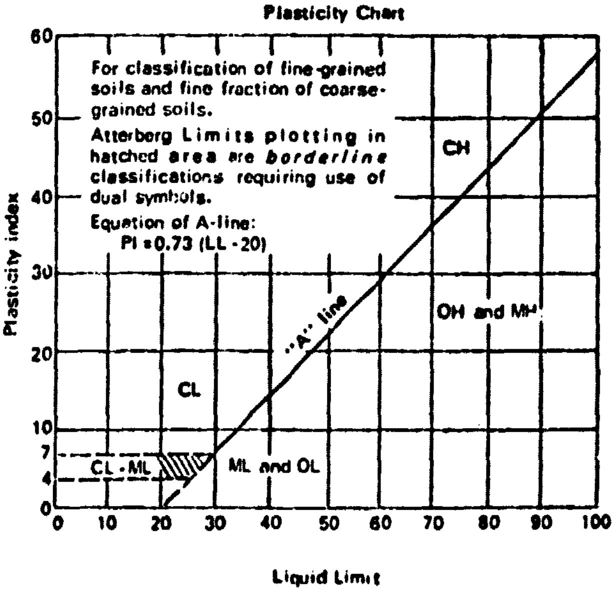
CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES

ASTM Designation: D 2487 – 69 AND D 2488 – 69

(Unified Soil Classification System)

Major divisions			Group symbols	Typical names	Classification criteria		
Coarse-grained soils More than 50% retained on No. 200 sieve*	Gravels 50% or more of coarse fraction retained on No. 4 sieve	Clean gravels	GW	Well-graded gravels and gravel-sand mixtures, little or no fines	Classification on basis of percentage of fines: Less than 5% pass No. 200 sieve . . . . . . GW, GP, SW, SP; More than 12% pass No. 200 sieve . . . . . . GM, GC, SM, SC; 5 to 12% pass No. 200 sieve . . . . . . *Borderline* classifications requiring use of dual symbols	$C_U = \frac{D_{60}}{D_{10}}$ greater than 4; $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines		Not meeting both criteria for GW	
		Gravels with fines	GM	Silty gravels, gravel-sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Atterberg limits plotting in hatched area are *borderline* classifications requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-clay mixtures		Atterberg limits above "A" line with P.I. greater than 7	
	Sands More than 50% of coarse fraction passes No. 4 sieve	Clean sands	SW	Well-graded sands and gravelly sands, little or no fines		$C_U = \frac{D_{60}}{D_{10}}$ greater than 6; $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP	Poorly graded sands and gravelly sands, little or no fines		Not meeting both criteria for SW	
		Sands with fines	SM	Silty sands, sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Atterberg limits plotting in hatched area are *borderline* classifications requiring use of dual symbols
			SC	Clayey sands, sand-clay mixtures		Atterberg limits above "A" line with P.I. greater than 7	
Fine-grained soils 50% or more passes No. 200 sieve*	Silts and clays Liquid limit 50% or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands	Plasticity Chart		
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL	Organic silts and organic silty clays of low plasticity			
	Silts and clays Liquid limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts			
			CH	Inorganic clays of high plasticity, fat clays			
			OH	Organic clays of medium to high plasticity			
	Highly organic soils		Pt	Peat, muck and other highly organic soils	*Based on the material passing the 3 in. (76 mm) sieve.		

Plasticity Chart



*Based on the material passing the 3 in. (76 mm) sieve.

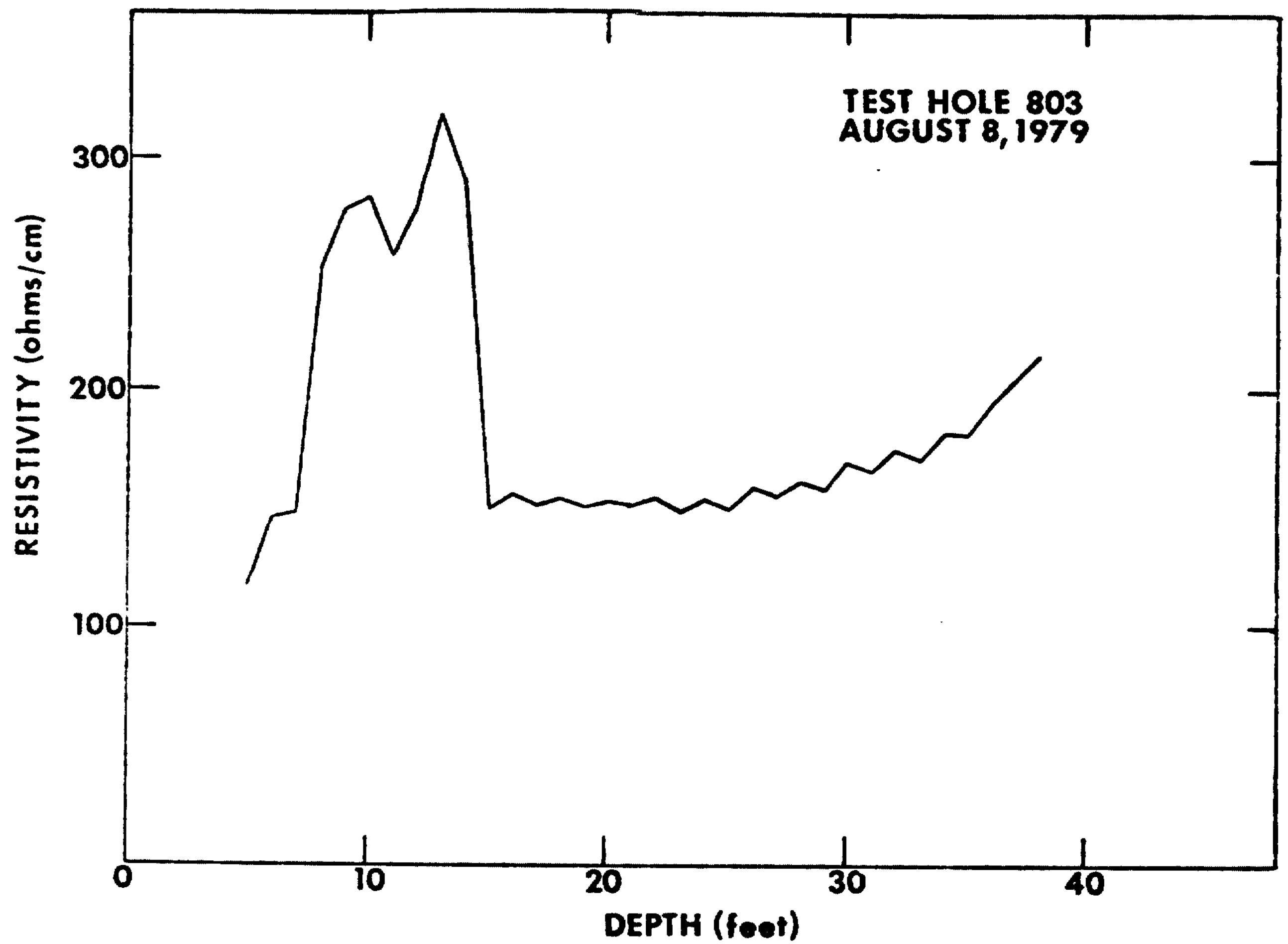


Fig. 3. Resistivity log for test hole 801. A high resistivity is indicative of permeable material.

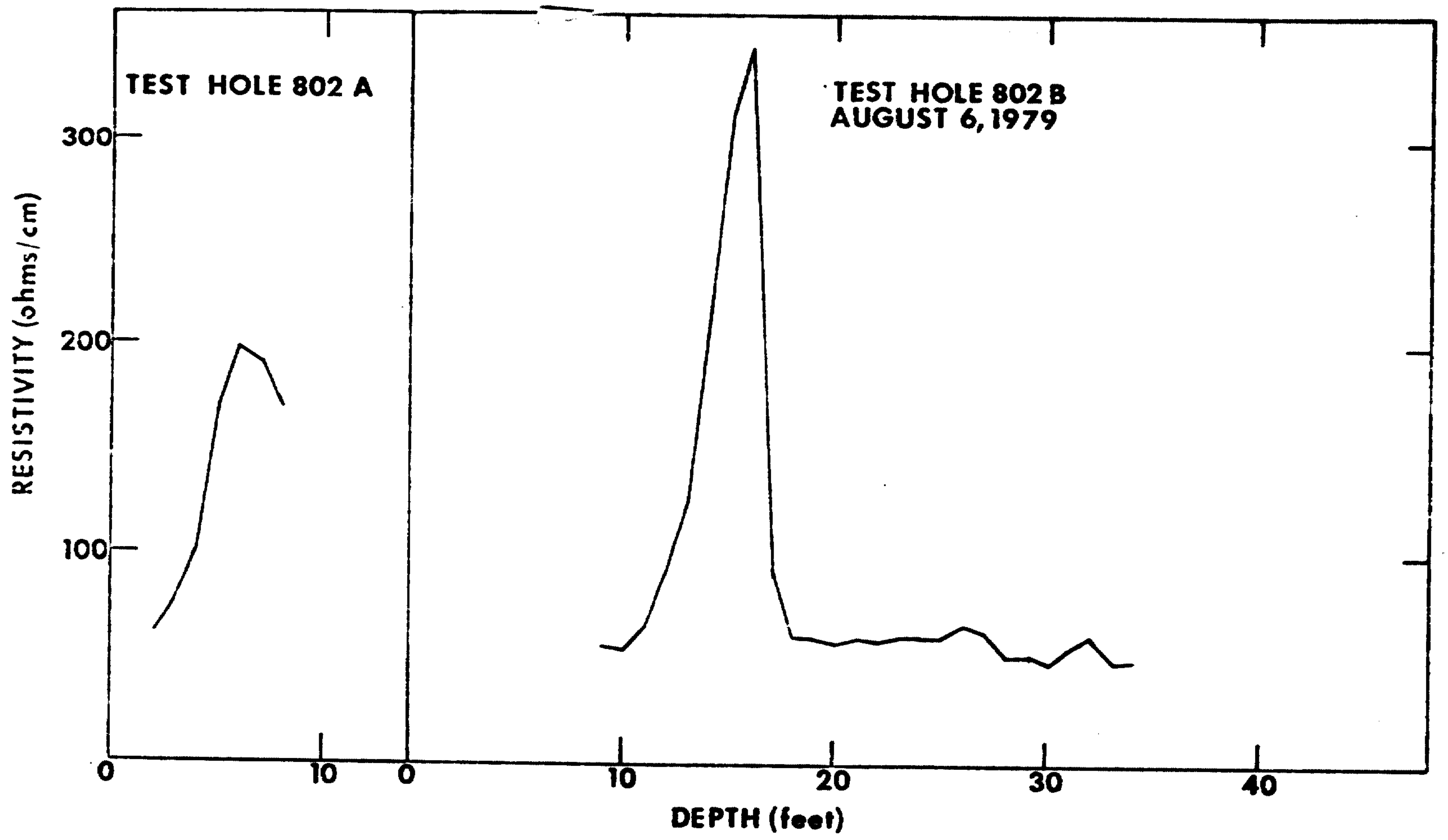


Fig. 4. Resistivity log for test holes 802A and B.

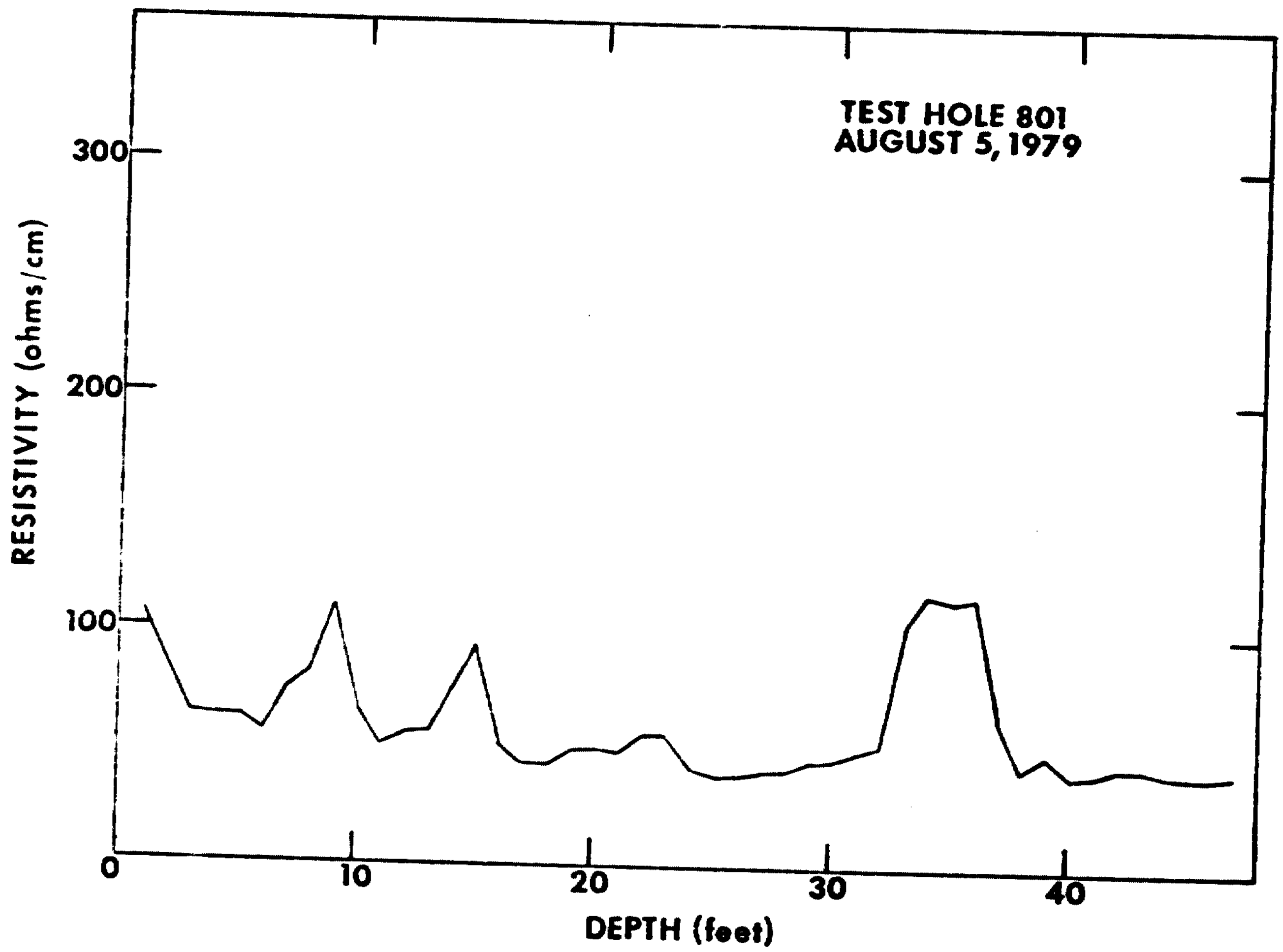


Fig. 5. Resistivity log for test hole 803.

SUMMARY

This completes the Six-Mile Creek Investigation. The attached letter from the State Conservationist summarizes the cooperative study between the Soil Conservation Service and the Remote Sensing Institute. This project has been a successful demonstration of the use of remote sensing in watershed planning and development. Information obtained from the investigation will be used to prepare the Preliminary Investigation Report (PIR) which will form the basis for the final Working Plan and Environmental Impact Statement. The PIR will be submitted to NASA upon completion.

United States Department of Agriculture
Soil Conservation Service
Federal Building
200 Fourth Street S. W.
Huron, South Dakota 57350

November 26, 1979

Mr. Victor Myers, Director
Remote Sensing Institute
South Dakota State University
Brookings, South Dakota 57007

Dear Mr. Myers:

We wish to thank you and your staff for the fine cooperation and help you have given us.

The cooperative study between the Remote Sensing Institute and the Soil Conservation Service on Six Mile Creek Watershed has been extremely useful and timely in the preparation of the watershed plan for flood-damage reduction and the development of water-based recreation.

Identification of land use and land-treatment needs are integral parts of the environmental assessment of the watershed. The remotely sensed data obtained by RSI is being used in this identification process. Digitized imagery has been analyzed and put in tabular form by RSI for soils mapping units and land used. The land use data has been superposed on watershed maps by RSI. SCS will pick out key soils which RSI will superpose on the land use maps. This data will be used by SCS to locate and quantify flood-prone areas and land treatment needs.

The proposed multipurpose reservoir designated SM-1B, located north of White, South Dakota, is being investigated as both a flood-water retarding and recreation reservoir. These combined purposes require both safety and waterholding capability considerations. Understanding the ground-water regime of the watershed and present and potential subsurface-water movement to and from the proposed reservoir are required in both safety and water holding capability considerations.

Infrared and near surface temperature scan data obtained by RSI were used to locate the boundaries of near surface permeable alluvium. Preliminary drilling was used to identify the subsurface materials. The location of the drill holes was selected using both the remotely sensed data and traditional site exploration methods. Ground-water observation wells and piezometers were installed to monitor the fluctuations in ground-water levels and head pressure. The monitoring is being continued by SCS to obtain adequate data on seasonal changes.

The remotely sensed data has made it possible to reduce the time and expense of subsurface drilling needed to identify the earth material characteristics. SCS has been able to more efficiently study the ground water conditions because the remotely sensed data has been used in decisions on the location and number of ground-water observation stations.

Cost and time efficiency have been improved by the use of remotely sensed data in the environmental assessment through reduction of time required for land use and land treatment inventories.

R. D. Swenson
State Conservationist

cc: Kenneth Huber, WRPSL, SCS, Huron
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